WHETTEN DITCH, SOLOMON CREEK, AND DRY RUN WATERSHEDS DIAGNOSTIC STUDY

Elkhart, Kosciusko, and
Noble Counties, Indiana

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Prepared For:

Elkhart County Soil and Water Conservation District
Nancy Brown, Program Manager
17746-B CR 34
Goshen, Indiana 46528-9261
(574) 533-3630

Prepared By:

J.F. New & Associates, Inc.
c/o Cornelia Sawatzky, Project Manager
708 Roosevelt Road
Walkerton, Indiana 46574
(574) 586-3400

WHETTEN DITCH, SOLOMON CREEK, AND DRY RUN WATERSHEDS DIAGNOSTIC STUDY EXECUTIVE SUMMARY

Whetten Ditch, Solomon Creek, and Dry Run drain 56 square miles (14,502 ha) of Elkhart, Kosciusko, and Noble Counties into the Elkhart River in the St. Joseph River Basin. The creeks and their tributaries originate in the Packerton Moraine left behind by the Wisconsian Glacial Period 21,000 years ago. The soils are predominantly sandy loams of low erosion potential. Many of the soil types in the study area are, however, limited for septic absorption fields. The original vegetation was primarily beech-maple and oak-hickory forest. Only about 9% of the watershed still remains forested. Approximately 87% of the watershed land use is agriculture, including 85% row cropping, with the remainder in pasture or hay. Much of the land is considered prime farmland due to the high nutrient content and available moisture in the loamy soils.

Conservation tillage practices are used on approximately 69% of the land in corn production and up to 93% of the fields planted to soybeans. This figure suggests that producers are using no-till or minimum till for soybeans and then rotating to corn and using partial or full-till. The majority of benefits from no-till are derived after three years and are minimized by rotating in and out of other tillage practices. Nutrient management techniques are under-utilized in the area and could be improved with more frequent soil testing, spot fertilization, and better consideration of legume nitrogen fixation and conservation tillage practices. Conservation tillage and better nutrient management will improve water quality by slowing and decreasing runoff volumes and decreasing nutrient loads to the waterways.

While no endangered, rare, or threatened species have been recently documented in the Whetten Ditch, Solomon Creek, or Dry Run Watersheds, invertebrate and fish communities are severely limited due to sediment loading and alterations of the habitat by ditch cleaning. The macroinvertebrate Index of Biotic Integrity (mIBI), an index which utilizes invertebrate community structure to measure water quality, documented a range of severely impacted (0.75) to just barely unimpaired (6.0). Habitat as assessed using the Qualitative Habitat Evaluation Index (QHEI) was also less than optimal for aquatic life uses. Water quality samples taken during storm events exceeded state standards for some chemical parameters and for *E. coli* at many sample sites.

The study watershed area was divided into smaller subwatersheds in order to prioritize the greatest needs for Best Management Practices (BMPs). The Dry Run Subwatershed has the greatest need for BMP implementation followed by the Whetten Ditch Subwatershed. Potential recommended land management treatments in the watershed included: wetland restoration, filter strip installation, bank stabilization, livestock fencing, buffer zone establishment, revegetation of exposed areas, and grassed waterway construction. Coordination with the County Drainage Boards for stream and riparian area conservation, management at the watershed-level, and public education and outreach were also recommended.

ACKNOWLEDGEMENTS

This Watershed Study was performed with funding from the Indiana Department of Natural Resources – Division of Soil Conservation and the Elkhart County Soil and Water Conservation District. J.F. New and Associates, Inc. and Indiana University – School of Public and Environmental Affairs documented the historical information available, completed tributary stream sampling for nutrient and sediment loading, and modeled nutrient and sediment loading to major rivers. Nancy Brown of the Elkhart County Soil and Water Conservation District and Beverly Stevenson, the Resource Conservationist with the USDA-NRCS provided initiative and assistance in getting this study completed. Significant contributors to this study included: Todd Davis, Stacey Sobat, and Chuck Bell with IDEM; Jim Lake and Gene Matzat with the Purdue Cooperative Extension Agency; Jill Hoffmann, Brant Fisher, Ron Hellmich, and Jed Pearson with the IDNR; staff of the Elkhart County and Noble County Surveyor's Offices; Clark Reed with the town of Cromwell; Dan Harper with Maple Leaf Farms; Tim Woodward, the superintendent of the Turkey Creek Sewer District; Deb Conley with the Elkhart County Economic Redevelopment Office; Stacey McGinnis and other Noble County Soil and Water Conservation District staff members. Authors of this report included William Jones, Melissa Clark, and Nick Haxton at Indiana University and Cornelia Sawatzky, Marianne Giolitto, John Richardson, and Steve Zimmerman at J.F. New and Associates, Inc. The report was peer-reviewed in its entirety by Jill Hoffmann of the IDNR Division of Soil Conservation, Kent Tracey of the IDNR Division of Soil Conservation, and Matt Jarvis the Regional Watershed Conservationist.

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INTRODUCTION

The Whetten Ditch, Solomon Creek, and Dry Run Watersheds are located southeast of Goshen and north-northeast of Lake Wawasee in Elkhart, Kosciusko, and Noble Counties, Indiana (Figure 1). Together the three watersheds drain about 36,242 acres. They encompass all of two 14-digit watersheds, the Solomon Creek-Meyer/Hire Ditch Watershed (HUC 04050001190060) and the Solomon Creek-Headwaters Watershed (HUC 04050001190050) and part of two others (Elkhart River-Whetten Ditch Watershed HUC 04050001190070 and Elkhart River-Dry Run Watershed HUC 04050001190040). The study area lies within Benton and Jackson Townships in Elkhart County, Turkey Creek Township in Kosciusko County, and Sparta Township in Noble County. For the purpose of this study, the watershed was further divided into ten smaller subwatersheds (Figure 2).

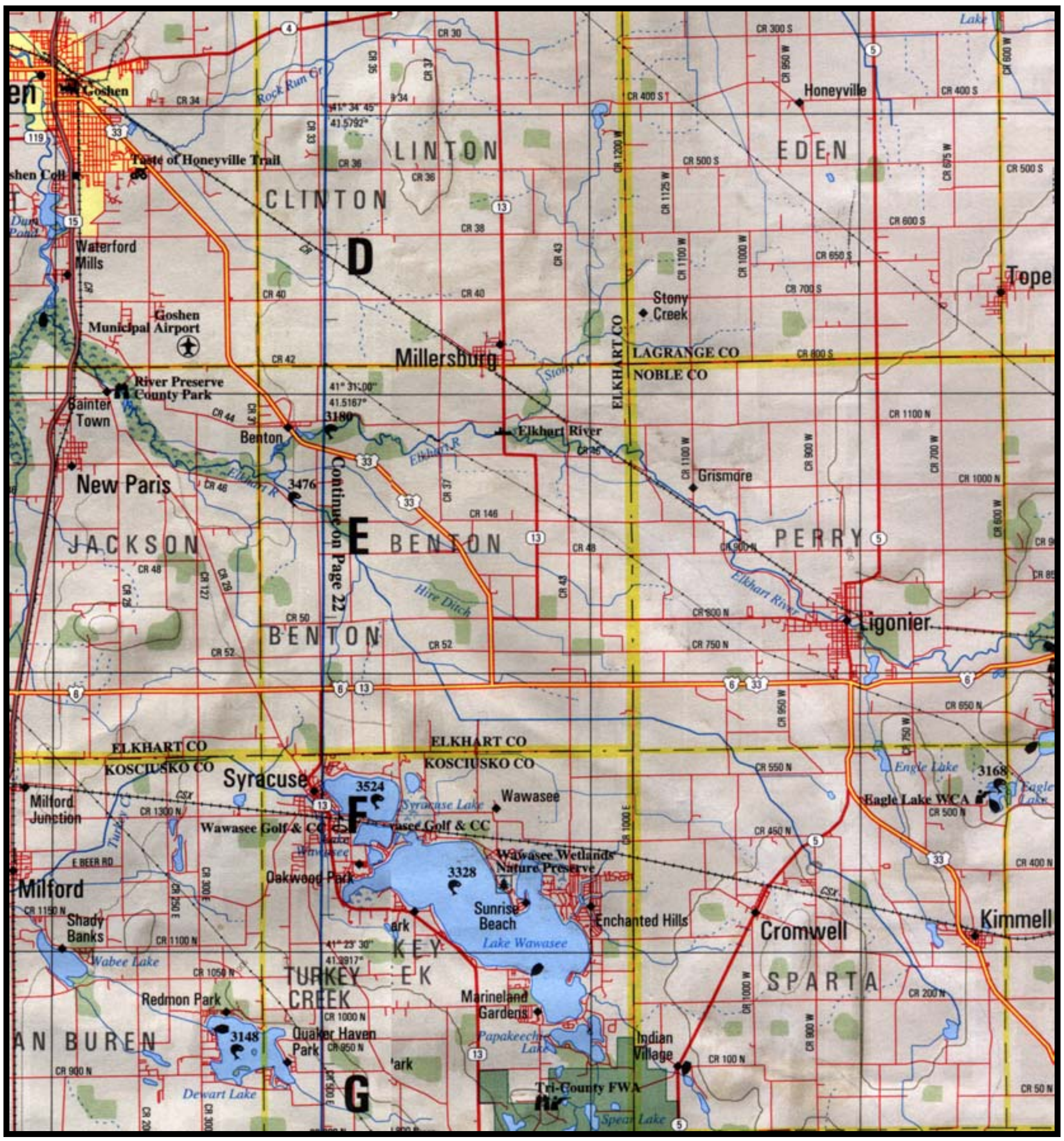


FIGURE 1. Study location map.

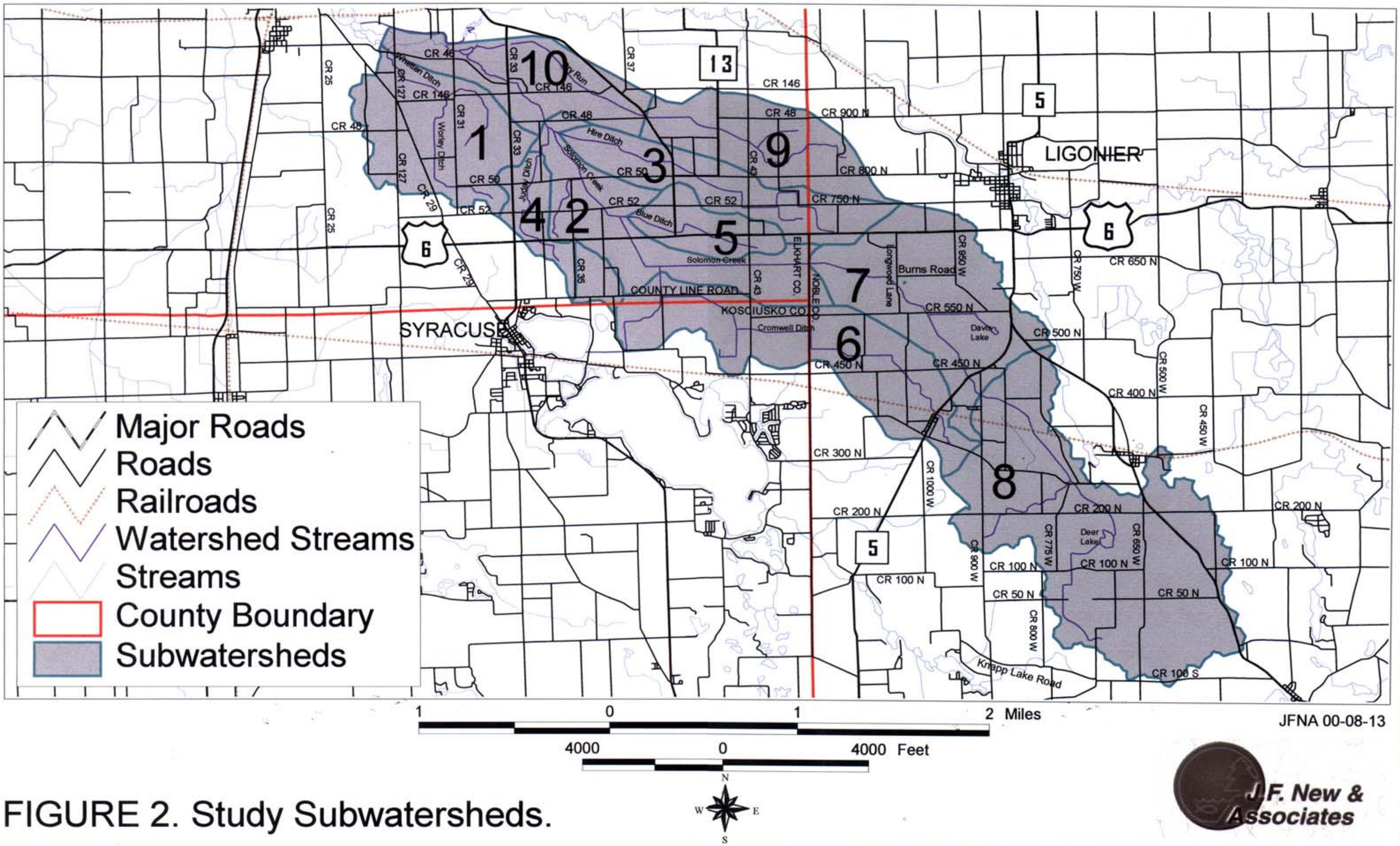


FIGURE 2. Study Subwatersheds.

The watershed is part of the 8-digit St. Joseph Watershed HUC 05120102 (Figure 3). Water from Whetten Ditch, Solomon Creek, and Dry Run discharges into the Elkhart River just north of Syracuse, Indiana. The Elkhart River flows northwest where it joins the St. Joseph River in the city of Elkhart. Eventually the St. Joseph River reaches Lake Michigan in southwestern Michigan near the cities of St. Joseph and Benton Harbor.

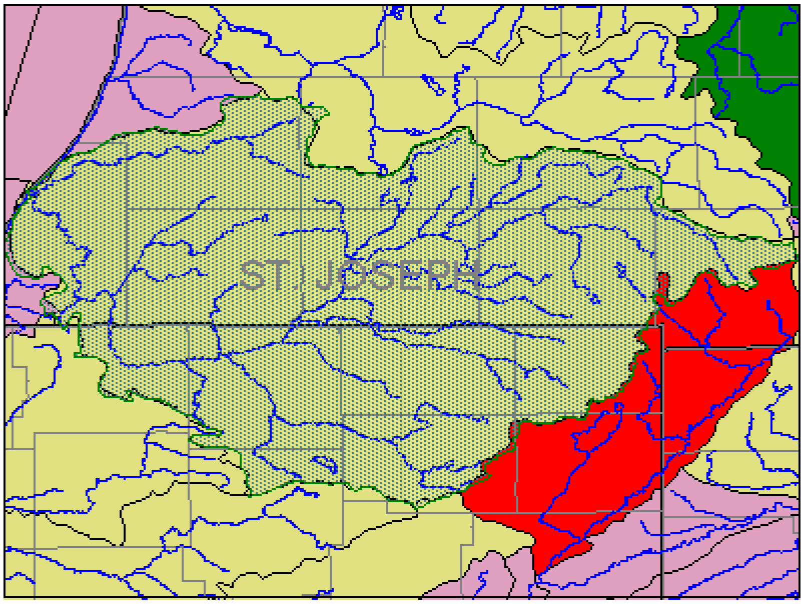


FIGURE 3. St. Joseph River Basin.

It is important to note that all the study streams except Solomon Creek itself are legal drains. Legal drains are necessary for water conveyance to sustain a variety of land uses, including agriculture. Disturbance to the system is inevitable due to periodic drainage improvement projects. Additionally, projects constructed within the drainage easement require County Drainage Board permission. Some projects may not be permitted should they impede drainage. Other permits from the U.S. Army Corps of Engineers (ACOE), the Indiana Department of Environmental Management (IDEM), and the Indiana Department of Natural Resources (IDNR) may also be required depending on the type of project.

The drainage basin of the Solomon Creek area was formed during the most recent retreat of the Pleistocene or Quaternary Era. The advance and retreat of the Ontario-Erie Lobe of the last Wisconsian glaciation and the deposits left by the lobe shaped much of the landscape found in the northern two-thirds of Indiana (Wayne, 1966). In the study area, the receding glacier left nearly level to rolling topography characterized by "numerous lakes, kettle holes, sandy and gravelly knolls and ridges and outwash plains" (Ulrich, 1966).

The study watershed is located in the central portion of the Northern Lakes Natural Region (Homoya et al., 1985). The Northern Lakes Natural Region occupies the north central and northeastern area of the state and is bordered by the Eel River on the southeast and the western side of the Maxinkuckee Moraine on the west. Prior to European settlement, the region was a mixture of numerous natural community types including bog, fen, marsh, prairie, sedge meadow, swamp, seep spring, lake and deciduous forest (Homoya et al., 1985). The dry to dry-mesic uplands which dominate the landscape were likely forested with red oak, white oak, black oak, shagbark hickory, and pignut hickory. More mesic areas probably harbored beech, sugar maple, black maple, and tulip poplar with sycamore, American elm, red elm, green ash, silver maple, red maple, cottonwood, hackberry, and honey locust dominating the floodplain forests. The first plat of Indiana by the General Land Surveyors documented beech-maple forests as comprising 50% or more of the original vegetation of the state while oak-hickory forests comprised about 29% (Petty and Jackson, 1966). The Northern Lake Natural Region also contains more bog habitat than any other region. The bogs are typically composed of a *Sphagnum* moss mat overlying a glacial depression.

Changes in land use have altered the watersheds' natural landscape. Settlers to the region drained wet areas and cleared forests in order to farm soils rich in both nutrients and humic material (decaying organic matter). However, this layer of rich soil was thin and years of crop removal and erosion depleted nutrient supplies. Around 1850, fertilization with potassium and phosphorus began. Fertilization had no effect on crop yield until 1940 when Dr. George Scarseth discovered that massive doses of nitrogen could significantly increase productivity. Technology and industry have increased and continue to increase farm production. Today, approximately 87% of the watershed is utilized for agricultural purposes.

Installation of subsurface tile drain networks, excavation of drainage channels, and straightening of streams has resulted in conversion of prairies and wetlands to agriculture. The effect of these drainage activities on water quality has been negative, resulting in off-site, downstream water flow and quality concerns. In a review of agricultural practices and their impacts on the natural structure and function of aquatic systems, Menzel (1983) concluded that effects other than water quality problems have emerged. These include alterations in water quantity, habitat structure, and energy transfer within streams.

Few studies have been conducted to document water quality and health within the Whetten Ditch, Solomon Creek, or Dry Run Watersheds. However, the 1998 Indiana Department of Environmental Management 303(d) report to the U.S. Environmental Protection Agency indicates non-support of contact recreation beneficial uses due to high levels of *E. coli* for the entire mainstem of the Elkhart River. Evidently, human impacts within this area of the St. Joseph River Watershed are having an adverse effect on water quality and beneficial uses.

Because there is little information about this watershed and in order to gain a better understanding of it, the Elkhart County Soil and Water Conservation District applied for and received funding through the Indiana Department of Natural Resources Lake and River Enhancement Program for a watershed diagnostic study. The purpose of this study is to describe the conditions in the watershed, identify potential problems, and make prioritized recommendations addressing these problems. This study includes a review of historical data and information, correspondence with landowners, business owners, and state and local regulatory agencies, collection of stream water quality samples and benthic macroinvertebrates, stream habitat quality evaluation, and field investigations identifying land use patterns and locations for best management practice (BMP) installation. This report documents the results of the study.

REVIEW OF EXISTING INFORMATION

Population and Demographics

Population sizes have dramatically increased in Elkhart, Kosciusko, and Noble Counties since 1900 (STATS Indiana, 2001). The 2000 census recorded 15% more people living in Elkhart County than lived there 10 years ago. On average, about 82 people per square mile live in the three townships encompassed by the study watersheds (Table 1). Cromwell, the only incorporated town in the study area, was home to 394 people in 1990 and 426 people in 2000.

TABLE 1. Population structure of the four townships that either border or are encompassed by the study watersheds. It is important to note that the Turkey Creek Township in Kosciusko County includes the town of Syracuse and populations living around Lake Wawasee, neither of which are in the Solomon Creek Drainage.

County	Township	Township Population	People/square mile
Elkhart	Benton	2,342	65
Elkhart	Jackson	3,409	95
Kosciusko	Turkey Creek	9,032	251
Noble	Sparta	3,111	86

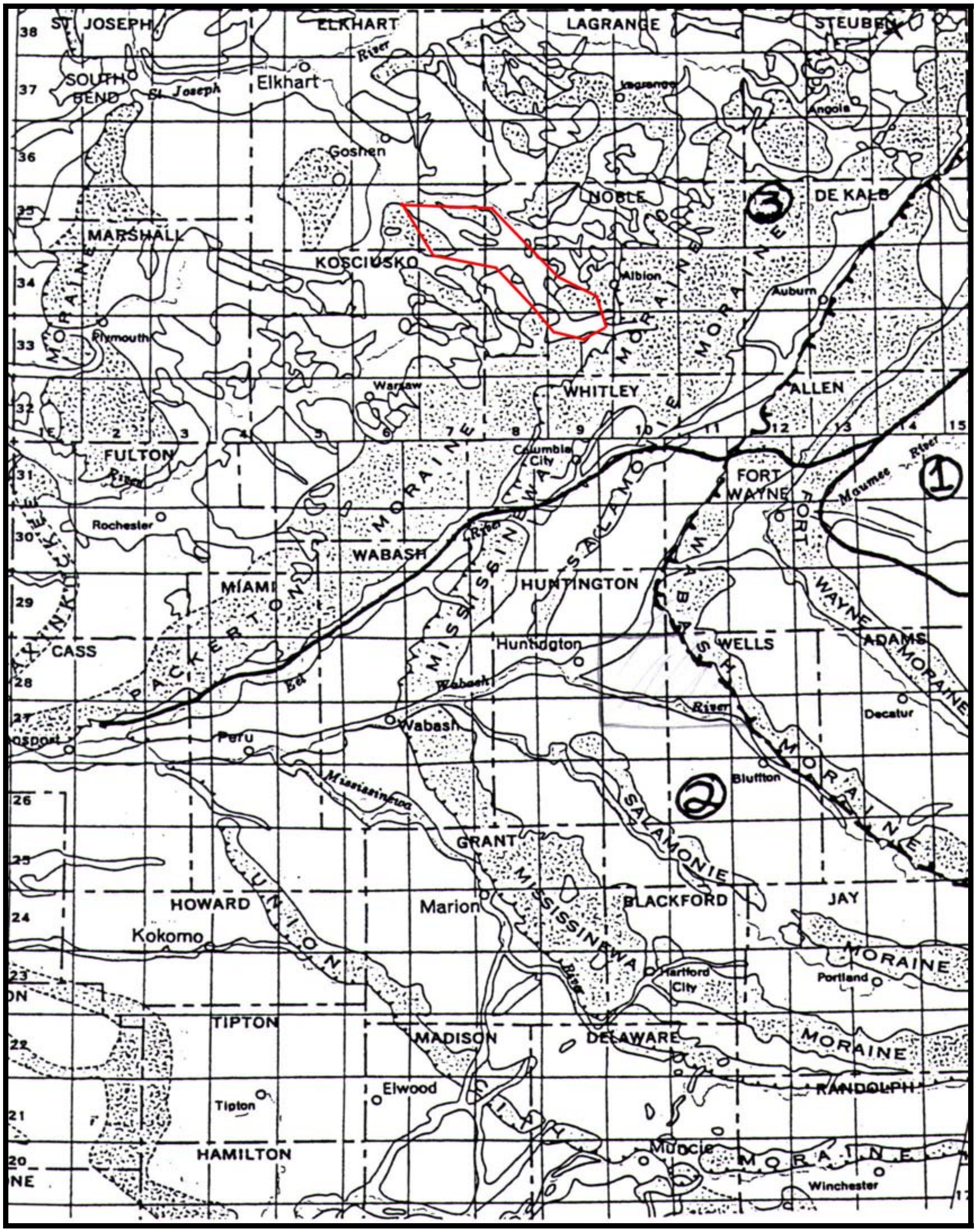
Source: STATS Indiana, 2001.

Physiography and Geology

The surficial physiography and geology of the study watershed area is the result of the most recent glacial period known as the Wisconsin Age that began about 70,000 years ago. Prior to the Wisconsin Age, Indiana had been glaciated twice, though the Wisconsin glacier can be credited with building northeastern topography in Indiana. During the main advance about 21,000 years ago, the Wisconsian glacier covered two-thirds of the state. Numerous glacial advances and retreats resulted in moraine deposition and the formation of Indiana topography as it is known today.

The retreat of the Huron-Saginaw Lobe of the Wisconsin ice sheet deposited the Packerton Moraine (Figure 4) and established the current topography of the study watershed about 15,000 years ago. Consequently, the retreat covered the area with a thick, complex deposit of glacial material that is over 450 feet thick in some places (Homoya et al., 1985). Glacial topography of the area is also complex and varied composed of kettles, moraines, outwash plains, kames (irregular, short ridge or hill of stratified glacial drift), and valleys. Most of Indiana's lakes were formed during the advance and retreat of the Huron-Saginaw Lobe.

In physiographic terms, the Whetten Ditch, Solomon Creek, and Dry Run Watersheds are part of the Steuben Morainal Lake Area (Schneider, 1966). The Steuben Morainal Lake Area is characterized by more physiographic and topographic variety than any other physiographic unit in Indiana. Knob and kettle end moraine topography can be found throughout the Packerton Moraine. The knob outcroppings are composed of ice-contact sand and gravel deposits (kame complexes) or glacial till material. The watershed drainages themselves were probably glacial meltwater channels leading to the broad outwash plain currently occupied by the Elkhart River. Streams in the area typically are clear and of medium to low gradient with sandy gravel substrates.



Map Source: Atlas of Mineral Resources of Indiana, Map No. 10.

FIGURE 4. Moraine deposits in northern Indiana from the Wisconsin Glacial Period.

The glacial topography of the area is underlain by shale bedrock formed during the Devonian and Mississippian Ages about 20 to 60 million years ago (Gutschick, 1966). The bedrock slopes at about 30 ft/mi to the northeast and is part of the Michigan Basin (Arihood, 1998). Bedrock elevations vary between about 275-710 feet above sea level in the study area. Unconsolidated material directly above the bedrock contains aquifers which serve as the water source for the area.

Watershed Physical Characteristics

The Whetten Ditch, Solomon Creek, and Dry Run Watersheds total 35,821 acres (14,502 ha or 56 square miles) and are part of the St. Joseph River Basin. Water from Whetten Ditch, Solomon Creek, and Dry Run discharges into the Elkhart River which flows northwest where it joins the St. Joseph River in the city of Elkhart. Eventually the St. Joseph River reaches Lake Michigan in southwestern Michigan near the cities of St. Joseph and Benton Harbor.

Tables 2 and 3 contain overview data for the watershed including subwatershed area and stream lengths for all named streams. Subwatershed boundaries were defined based on topography and sample locations that represent smaller drainages chosen for the study. It is often desirable to consider subwatersheds or subdrainages because: 1) human communities are organized within small areas (like the town of Cromwell is located on Solomon Creek in the Meyer/Cromwell Subwatershed); 2) the subdrainage scale allows for the identification of areas where specific management practices can be recommended and instituted; 3) large watershed units may be too expensive to restore while treatment of small areas may provide measurable water quality improvement (O'Leary et al., 2001). Additionally, watershed division allows for prioritization of resources to land areas of greatest concern where conservation practices may have the greatest benefit.

TABLE 2. Watershed area for the ten study subwatersheds and for the study area as a whole.

Watershed/Subwatershed	Watershed/Subwatershed Number	Watershed Area
Whetten Ditch Subwatershed	1	3,528 acres (1,428 ha)
Solomon Creek West Subwatershed	2	3,311 acres (1,340 ha)
Hire Ditch Subwatershed	3	2,644 acres (1,070 ha)
Juday Ditch Subwatershed	4	922 acres (373 ha)
Blue Ditch Subwatershed	5	1,251 acres (506 ha)
Meyer/Cromwell Ditch Subwatershed	6	5,119 acres (2,072 ha)
Solomon Creek East Subwatershed	7	4,721 acres (1,911 ha)
Solomon Creek Headwaters Subwatershed	8	9,256 acres (3,747 ha)
Dry Run Subwatershed	9	2,760 acres (1,117 ha)
Mouths of Solomon Creek and Dry Run Subwatershed	10	2,730 acres (1,105 ha)
Study Watershed Total		**36,242 acres (14,673 ha)**

TABLE 3. Stream length of all named streams and length of the entire study drainage system.

Creek/Ditch	Stream Length (miles)	Stream Length (km)
Whetten Ditch	3.2	5.1
Worley Ditch	2.7	4.3
Juday Ditch	2.9	4.6
Dry Run	7.2	11.6
Hire Ditch	4.9	8.0
Blue Ditch	2.6	4.1
Meyer/Cromwell Ditch	9.6	15.4
Solomon Creek	18.9	30.0
Unnamed Tributaries	4.7	7.6
Study Drainage System Total	**56.4**	**90.8**

Climate

Indiana Climate

Indiana's climate can be described as temperate with cold winters and warm summers. "Imposed on the well known daily and seasonal temperature fluctuations are changes occurring every few days as surges of polar air move southward or tropical air moves northward. These changes are more frequent and pronounced in the winter than in the summer. A winter may be unusually cold or a summer cool if the influence of polar air is persistent. Similarly, a summer may be unusually warm or a winter mild if air of tropical origin predominates. The action between these two air masses of contrasting temperature, humidity, and density fosters the development of low-pressure centers that move generally eastward and frequently pass over or close to the state, resulting in abundant rainfall. These systems are least active in midsummer and during this season frequently pass north of Indiana" (National Climatic Data Center, 1976). Prevailing winds are generally from the southwest, but are more persistent and blow from a northerly direction during the winter months. Flooding is common in Indiana and occurs in some part of the state almost every year. The months of greatest flooding frequency are December through April. Causes of flooding vary from prolonged periods of heavy rain to precipitation falling on snow and frozen ground.

Study Watershed Climate

The climate of the study watershed is characterized as having four well-defined seasons of the year. Winters average 25.9ºF (-3.4ºC), while summers are warm, averaging 71ºF (21.7ºC). The growing season typically begins in early May and ends in early October. Yearly annual rainfall averages 35.3 inches (89.7 cm), while winter snowfall averages about 25.9 inches (65.8 cm). The ten-year frequency, one-hour duration, rainfall intensity for the area is 1.65 inches/hour. During summers, relative humidity varies from about 40 percent in midafternoon to near 90 percent at dawn. Prevailing winds typically blow from the southwest, but westerly and northwesterly winds predominate in the winter.

In 2000, over 37 inches (94 cm) of precipitation (Table 4) was recorded at Waterford Mill near Goshen in Elkhart County (http://shadow.agry.purdue.edu/sc.index.html). This amount exceeded that received during 1999, which was widely recognized as a drought year. When compared to the 30-year average rainfall for the area, 2000 exceeded the average by almost two inches. Year

2001 was characterized by significant wetter-than-normal and drier-than-normal periods. Spring and summer months were uncharacteristically wet. By October of 2001, the area had received 11 inches more rain than would have been received by a normal October.

TABLE 4. Monthly rainfall data (in inches) for year 2000 and 2001 as compared to average monthly rainfall. All data was recorded at the Waterford Mill gage station directly south of Goshen except data for March 2001 which was obtained from the Ligonier gage station. Averages are based on available weather observations taken during the years of 1961-1990 (http://shadow.agry.purdue.edu/sc.index.html).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
2000	1.70	2.00	2.09	3.95	3.57	5.29	1.96	3.42	4.64	2.43	2.89	3.21	37.15
2001	0.59	1.93	0.62	3.32	4.64	4.33	5.47	8.27	4.47	7.26	1.82	2.61	45.33
Average	1.59	1.60	2.72	3.45	3.20	3.69	3.62	3.72	3.45	2.79	2.72	2.75	35.30

Soils

Introduction

The soil types found in Elkhart, Kosciusko, and Noble Counties are a product of the original parent materials deposited by the glaciers that covered the area 12,000 to 15,000 years ago. The main parent materials found in the counties are glacial outwash and till, ice-contact sand and gravel deposits, alluvium, and organic materials that were left as the glaciers receded. The interaction of these parent materials with the physical, chemical, and biological variables found in the area (climate, plant and animal life), time, and the physical and mineralogical composition of the parent material formed the soils located in the three counties today.

Surficial Saginaw-Huron Lobe deposits are characteristically sand, sandy loams, and gravel within and west of the Packerton moraine, the somewhat diffuse morainal structure drained by the watershed (Figure 4). Due to the variable and unconsolidated nature of these Saginaw-Huron glacial deposits, the USDA soils surveys of Elkhart (Kirschner and McCarter, 1974), Kosciusko (Staley, 1989) and Noble (McCarter, 1977) Counties classify soil associations within the study area into 11 different types even at a general level. Table 5 contains information on these general soil associations and where they may be found within the general topography.

TABLE 5. Characteristics of general soil associations found within the study watershed.

County	Association	Description	Texture	Formation Process	Location
Elkhart	Oshtemo-Fox	sandy loams; loamy sands	coarse	under mixed hardwoods in sandy outwash or alluvium	major drainage-ways; outwash plains; knolls and ridges of uplands
Elkhart	Riddles-Crosby-Miami	sandy loams; loams; clay loams	moderately coarse to moderately fine	under mixed hardwoods in medium textured glacial till or drift	upland areas of glacial till plain
Kosciusko	Houghton-Palms	muck; silty clay loams	fine	in organic material deposits	broad flats, drainageways and depressions; around lakes
Kosciusko	Ormas-Kosciusko	loamy sands; sandy loams	coarse	in outwash deposits	outwash plains; tops on knolls and ridges
Kosciusko	Sebewa-Gilford	loams	medium to fine	in outwash deposits	outwash plains and terraces
Noble	Fox-Oshtemo	sandy loams; loamy sands	coarse to moderately coarse	under mixed hardwoods in moderately coarse glacial outwash	outwash plains and uplands
Noble	Homer-Sebewa	sands; gravelly sands	coarse	in medium textured glacial outwash	flats between and in depressions on outwash plains
Noble	Miami-Riddles-Brookston	loams; sandy loams; silt loams	moderately coarse to moderately fine	under mixed hardwoods in medium textured glacial drift and till	flats or knolls along drainage-ways; depressions in the upland
Noble	Warsaw-Parr	loams	medium	under prairie grass and scattered trees in medium textured glacial drift and till	outwash plains
Noble	Morley-Blount	silt loams; silty clay loams	medium to moderately fine	under mixed hardwoods in moderately fine textured glacial till	knolls, flats, and ridges along drainageways in the upland
Noble	Houghton-Edwards-Adrian	muck	fine	under wetland plants in deposits of organic material	depressional areas in upland or outwash plains

Source: Kirschner and McCarter, 1974; Staley, 1989; and McCarter, 1977.

Highly Erodible Soils

Soils in the watersheds and their ability to erode or sustain certain land use practices, can impact the water quality of the river systems with which they converge. For example, highly erodible soils are, as their name implies, easily erodible. Soils that erode from the landscape are transported to waterways where they impair water quality, interfere with recreational uses, and impair aquatic habitat and health. In addition, such soils carry attached nutrients, which further impair water quality by increasing production of plant and algae growth. Soil-associated chemicals like some herbicides and pesticides can kill aquatic life and damage water quality.

Soil unit names considered highly erodible by the Natural Resources Conservation Service (NRCS) are included in Table 6. It is important to note that highly erodible soil designations are based on county-wide soil surveys, and the soils at various locations have not necessarily been field checked. Elkhart County only lists four highly erodible soil types due to its location on the flatter outwash and lacustrine plain area. Kosciusko and Noble Counties, which lie completely within the more variable terrain of the morainal lake area, list 10 and 33 highly erodible soil types respectively. The portion of the watershed lying in Elkhart and Kosciusko Counties contains very little highly erodible soil, while the study area within Noble County boundaries contains significantly larger acreages of erodible soil. The exact areas where soil erosion could be of concern will be discussed in the Highly Erodible Land (HEL) section.

TABLE 6. Soil units within the watershed area considered highly erodible by the NRCS offices of Elkhart, Kosciusko, and Noble Counties.

Soil Unit	Soil Name	Soil Description
MoD2	Miami loam	12-18% slopes, eroded
MrD3	Miami clay loam	12-18% slopes, severely eroded
MvC	Morley loam	6-12% slopes
BlB2	Blount silt loam	2-4% slopes, eroded
BoC	Boyer loamy sand	6-12% slopes
BoD2	Boyer loamy sand	12-18% slopes, eroded
CcC3	Casco sandy clay loam	8-15% slopes, severely eroded
ChC	Chelsea fine sand	6-12% slopes
FoC2	Fox sandy loam	6-12% slopes, eroded
FsD2, FsE2	Fox-Casco sandy loam	12-25% slopes, eroded
MfB2-MfE2	Miami loam	2-25% slopes, eroded
MgC3	Miami clay loam	6-18% slopes, severely eroded
MrB2-MrD2	Morley silt loam	2-18% slopes, eroded
MsC3, MsD3	Morley silty clay loam	6-18% slopes, severely eroded
MtE	Morley soils	18-25% slopes
MuC2	Morley, Miami, Rawson loams	6-12% slopes, eroded
OsC	Oshtemo loamy sand	6-12% slopes
RaC2	Rawson sandy loam	6-12% slopes, eroded
RbB	Rawson loam	2-6% slopes
RdB2	Rawson, Morley, and Miami loams	2-6% slopes, eroded
RsC2, RsD2	Riddles sandy loam	6-18% slopes, eroded

Source: 1988 USDA/SCS Indiana Technical Guide Section II-C for Elkhart County; 1987 USDA/SCS Indiana Technical Guide Section II-C for Kosciusko County; 1987 USDA/SCS Indiana Technical Guide Section II-C for Noble County.

These soil types are limited for certain classes of land use, and erosion hazard is a major management concern. Miami loam and clay loam soils (MoD2 and MrD3) are erosion prone, and due to moderately slow permeability, runoff occurs rapidly. Although little steeply sloped

Miami loam (MoD2) and Miami clay loam (MrD3) soils exist within the study watersheds, these soils, found on knolls and breaks along drainageways, are particularly erosion vulnerable. Though not well suited for crop cultivation, conservation practices are necessary if the land is to be cultivated. Erosion is also the primary risk associated with Morley loam soils (MvC). Due to soil compaction propensity, strong sloping, and moderately slow permeability, erosion must be prevented by incorporation of conservation practices.

Erosion, soil blowing, rapid runoff, and organic matter depletion are risks associated with the remaining soils listed in Table 6. Many of the soils are suited to cultivation as long as erosion is controlled with Best Management Practices (BMPs) and soil organic matter is maintained. However, Boyer loamy sand (BoD2), Casco sandy clay loam (CcC3), the Fox-Casco sandy loams (FsD2-FsE2), Miami clay loam (MgC3), and Morley soils (MtE) are not suited for row crop cultivation under most circumstances.

Highly Erodible Land

Highly Erodible Land (HEL) is a designation used by the Farm Service Agency (FSA). For a field or tract of land to be labeled HEL by the FSA, at least one-third of the parcel must be situated in highly erodible soils and the tract of land must be used for production. Unlike the soil survey, these fields must be field checked to ensure the accuracy of the mapped soils types. Farm fields mapped as HEL are required to file a conservation plan with the FSA in order to maintain eligibility for any financial assistance from the USDA. Figure 5 shows the location of HEL fields which are also farmed in the study watershed. Approximately, 3,428 acres (1,388 ha) of HEL exist within boundaries of the study watershed. This is about 10% of the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. It is important to note here that the FSA only tracks HEL if the tract of land is used to produce crops. Parcels of land may be highly erodible but not recorded as such if it is not used for production. Therefore, the 10% estimate may be an underestimate of the actual amount of HEL in the watersheds.

Table 7 breaks the information down by subwatershed. The Solomon Creek Headwaters Subwatershed has the most HEL acreage, and 28.9% of its watershed is mapped as HEL. A significant portion of the Solomon Creek West Subwatershed (27.8%) is considered HEL. The Whetten Ditch, Meyer/Cromwell, and Solomon Creek East Subwatersheds also contain some (though small) percentages of HEL.

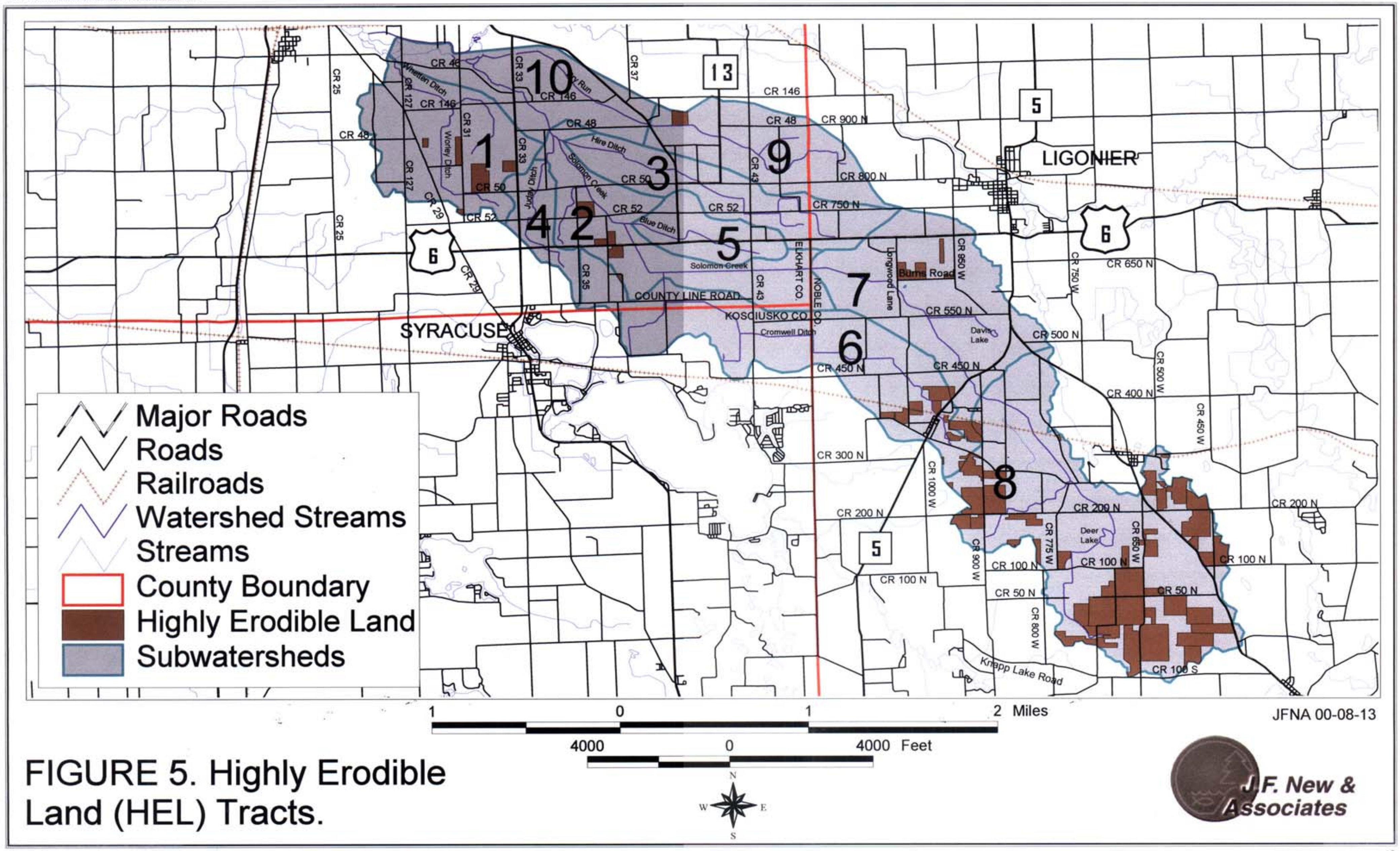


FIGURE 5. Highly Erodible Land (HEL) Tracts.

TABLE 7. Area mapped in highly erodible map units by subwatershed and percent of each subwatershed that is considered highly erodible.

Subwatershed	Acres	Hectares	Percent of Subwatershed
Whetten Ditch Subwatershed (1)	175	71	5.0%
Solomon Creek West Subwatershed (2)	134	54	27.8%
Hire Ditch Subwatershed (3)	0	0	0.0%
Juday Ditch Subwatershed (4)	0	0	0.0%
Blue Ditch Subwatershed (5)	0	0	0.0%
Meyer/Cromwell Ditch Subwatershed (6)	205	83	4.0%
Solomon Creek East Subwatershed (7)	192	78	4.1%
Solomon Creek Headwaters Subwatershed (8)	2,679	1,085	28.9%
Dry Run Subwatershed (9)	43	17	0.5%
Mouths of Solomon Creek and Dry Run Subwatershed (10)	0	0	0.0%
Total	**3,428**	**1,388**	**9.6%**

Source: GIS coverages based on information from the Farm Service Agencies of Elkhart, Kosciusko, and Noble Counties.

Figure 6 demonstrates that in general more of the HEL is concentrated higher in the watershed. Most highly erodible lands within a watershed typically occur in the headwaters where slopes are steeper causing greater soil erosion potential. Near the confluence of the streams with the Elkhart River, the Hire Ditch, Juday Ditch, Blue Ditch, Dry Run, and Mouth of Solomon Creek and Dry Run Subwatersheds contain very little or no HEL area.

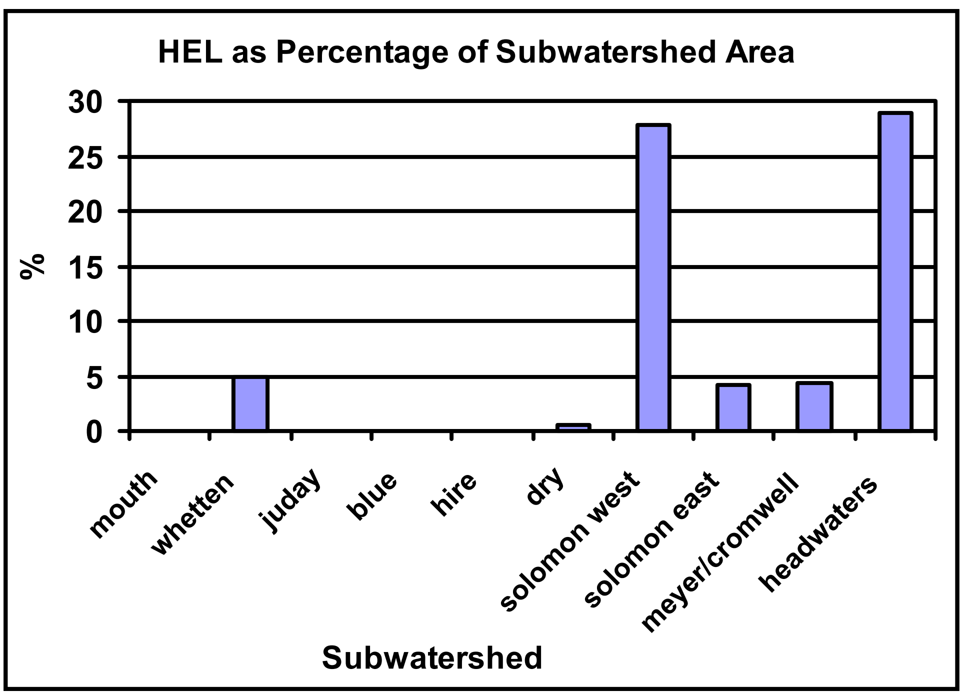


FIGURE 6. Highly erodible land as a percentage of subwatershed area.

When comparing Figures 6 and 7, it becomes apparent that of the tracts that have been mapped as HEL in the watershed, many are currently being used for row crop agriculture. This type of land use on highly erodible, marginal soils has definite implications for the receiving waterway's ability to support its beneficial uses. Consideration and implementation of Best Management Practices (BMPs) on these tracts is merited. BMPs will be discussed in more detail later in the report.

Considerations for On-Site Wastewater Disposal Systems

Background Information

Nearly half of Indiana's population lives in residences having private waste disposal systems. As is common in rural Indiana, septic tanks and septic tank absorption fields are utilized for wastewater treatment in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. This type of wastewater treatment system relies on the septic tank for primary treatment to remove solids and the soil for secondary treatment to reduce the remaining pollutants in the effluent to levels that protect surface and groundwater from contamination.

A variety of factors can affect a soil's ability to function as a septic absorption field. Seven soil characteristics are currently used to determine soil suitability for on-site sewage disposal systems: position in the landscape, slope, soil texture, soil structure, soil consistency, depth to limiting layers, and depth to seasonal high water table (Thomas, 1996). The ability of soil to treat effluent (waste discharge) depends on four factors: the amount of accessible soil particle surface area, the chemical properties of the surfaces, soil conditions like temperature, moisture, and oxygen content, and the types of pollutants present in the effluent (Cogger, 1989).

The amount of accessible soil particle surface area depends both on particle size and porosity. Because they are smaller, clay particles have a greater surface area per unit volume than silt or sand and therefore, a greater potential for chemical activity. However, soil surfaces only play a role if wastewater can contact them. Soils of high clay content or soils that have been compacted often have few pores that can be penetrated by water and are not suitable for septic systems because they are too impermeable. Additionally, some clays swell and expand on contact with water closing spaces and pores in the profile even more. On the other hand, very coarse soils may not offer satisfactory effluent treatment either because the water can travel so rapidly through the soil profile. Soils located on sloped land also may have difficulty in treating wastewater due to reduced contact time.

Chemical properties of the soil surfaces are also important for wastewater treatment. For example, clay materials all have imperfections in their crystal structure which gives them a negative charge along their surfaces. Due to their negative charge, they can bond cations of positive charge to their surfaces. However, many pollutants in wastewater are also negatively charged and are not attracted to the clays. Clays can help remove and inactivate bacteria, viruses, and some organic compounds.

Environmental soil conditions influence the microorganism community which ultimately carries out the treatment of wastewater. Factors like temperature, moisture, and oxygen availability influence microbial action. Excess water or ponding saturates soil pores and slows oxygen transfer. The soil may become anaerobic if oxygen is depleted. Decomposition process (and therefore, effluent treatment) becomes less efficient, slower, and less complete if oxygen is not available.

Many of the nutrients and pollutants of concern are removed safely if a septic system is sited correctly. Most soils have a large capacity to hold phosphate. On the other hand, nitrate (the end product of nitrogen metabolism in a properly functioning septic system) is very soluble in soil solution and is often leached to the groundwater. Care must be taken in siting the system to avoid well contamination. Nearly all organic matter in wastewater is biodegradable as long as oxygen is present. Pathogens can be both retained and inactivated within the soil as long as conditions are right. Bacteria and viruses are much smaller than other pathogenic organisms associated with wastewater and therefore, have a much greater potential for movement through the soil. Clay minerals and other soil components may adsorb them, but retention is not necessarily permanent. During storm flows, they may become resuspended in the soil solution and transported in the soil profile. Inactivation and destruction of pathogens occurs more rapidly in soils containing oxygen because sewage organisms compete poorly with the natural soil microorganisms, which are obligate aerobes requiring oxygen for life. Sewage organisms live longer under anaerobic conditions without oxygen and at lower soil temperatures because natural soil microbial activity is reduced.

The Study Watershed Area

Soil conditions such as slow permeability and high water table, coupled with poor design, faulty construction, and lack of maintenance reduce the average life span of septic systems in Indiana to 7-10 years (Jones and Yahner, 1994). Likewise, several onsite systems located in morainal soils in other neighboring areas are known to perform poorly or to have failed completely (Indiana University/Purdue University, 1996). Localized soil-geologic conditions are responsible for most of the problems. In fact in Wells County, the Indiana State Department of Health and the Wells County Health Board have instituted a moratorium on residential development within the Wabash End Moraine in an area known as “Buttermilk Ridge”, a part of Union Township (Section 14, T28N, R11E). Although no extensive studies have been conducted within the Packerton Moraine of the immediate watershed area, soil types there share similar soil composition characteristics with soils like those found in the Wabash End Moraine.

The NRCS ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields on soils in the moderately or severely limited categories generally requires special designs, planning, or maintenance to overcome the limitations. Table 8 summarizes the predominant soil series located in the study watershed area in terms of their suitability for use as a septic tank absorption field.

TABLE 8. Dominant soil types in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds and their suitability for on-site wastewater treatment systems.

Name	Symbol	Depth to Water Table	Suitability for Septic Absorption Field
Oshtemo loamy sand	OsA-E	>6 ft	Slight: 0-6% slopes Severe: 6-25% slopes due to rapid drainage (some hazard of polluting nearby wells)
Fox sandy loam	FoA-FoC2	>6 ft	Slight: 0-6% slopes Severe: 6-25% slopes due to rapid drainage (some hazard of polluting nearby wells)
Riddles sandy loam	RsA-RsE2	>6 ft	Slight: 0-6% slopes Severe: 6-25% slopes due to slope
Riddles loam	RtA-RtC2	>6 ft	Slight: 0-6% slopes Severe: 6-12% slopes due to slope
Crosby loam	CrA, CrB	1-3 ft	Severe: percs slowly, seasonal high water table
Miami loam	MoB2-MoD2	>6 ft	Moderate: 2-12% due to slow percolation Severe: 12-18% due to slow percolation and slope
Miami clay loam	MrC3-MrD3	>6 ft	Severe: percs slowly, present surface layer is subsoil material
Houghton muck	Ht, Hx	+1-1 ft	Severe: subsidence, ponding, percs slowly
Palms muck	Pa, Pb	+1-1 ft	Severe: subsidence, ponding
Ormas loamy sand	OrA-OrC	>6 ft	Severe: poor filter
Ormas loamy sand; sandy substrate	OtA-OtC	>6 ft	Severe: poor filter
Kosciusko sandy loam	KoA-KoE	>6 ft	Severe: poor filter
Kosciusko silt loam	KtA	>6 ft	Severe: poor filter
Kosciusko sandy clay loam	KxC3	>6 ft	Severe: poor filter
Sebewa loam	Se	+1-1 ft	Severe: seasonal high water table, ponding
Gilford sandy loam/mucky sandy loam	Gf, Gm	+0.5-1 ft	Severe: seasonal high water table, ponding
Homer loam	Hh	1-3	Severe: percs slowly, seasonal high water table
Brookston silt loam	Bx	0-1 ft	Severe: very poorly drained

Warsaw loam	WrA	>6 ft	Slight
Parr loam	PdA	>6 ft	Slight
Morley silt loam	MrB2-MrD2	3-6 ft	Severe: 0-6% slopes perc slowly; 6-18% slopes perc slowly, slope, and risk of effluent seepage at base of slope
Morley silty clay loam	MsC3-MsD3	3-6 ft	Severe: percs slowly, slope, and risk of effluent seepage at base of slope
Blount silt loam	BlA-BlB2	1-3 ft	Severe: poorly drained
Edwards muck	Ed, Em	0-1 ft	Severe: very poorly drained, organic material
Adrian muck	Ad, Am	0-1 ft	Severe: very poorly drained, organic material

Source: Soil Surveys of Elkhart, Kosciusko, and Noble Counties.

Of the 25 major soil types present in the study drainage, only the Warsaw loam (WrA) and the Parr loam (PdA) are suited for septic leachate treatment. The Oshtemo loamy sand (OsA, OsB), Fox sandy loam (FoA, FoB), and Riddles sandy loam (RsA, RsB) are also suited for treatment as long as they are situated on slopes of less than 6%. Systems installed on slopes steeper than 6% induce rapid drainage and improper leach field function; risks of groundwater and nearby surface water contamination are high.

The remaining 19 major soil types are moderately to severely limited for use as septic system substrate and are generally not conducive to the satisfactory operation of conventional on-site treatment systems. The Crosby (CrA, CrB) and Homer (Hh) loams, the Miami loam and clay loams (MoB2-MoD2 and MrC3-MrD3), the Sebewa loam (Se), the Gilford sandy loam and mucky sandy loam (Gf and Gm), and the Morley silt loam and silty clay loam (MrB2-MrD2 and MsC3-MsB3) tend to be wet, poorly drained soils of slow permeability. The Brookston (Bx) and Blount (BlA-BlB2) silt loam soils are also very poorly drained soils. High water tables especially during wet seasons can cause soil saturation and even ponding. Characteristic wetness can lead to anoxic conditions and improper treatment within leach fields. It is recommended that systems be: installed with perimeter subsurface drains to lower the water table, installed with an enlarged leach field to offset slow permeability, and constructed when the soil is dry to avoid soil sealing and compaction.

Due to ponding and low soil strength which causes subsidence, Houghton (Ht, Hx), Palms (Pa, Pb), Edwards (Ed, Em), and Adrian (Ad, Am) muck soils are also severely compromised for septic effluent treatment. The water table is often within one foot of the surface, and because the water table is often at the same level as surface water features (like lakes and streams), achieving proper septic field drainage may be impossible (McCarter, 1977).

Soils belonging to the Ormas and Kosciusko Series are well-drained, highly permeable soils. All soil, subsoil, and underlying material layers are highly permeable. These soils are severely limited for effluent treatment because drainage time is too rapid to allow for filtration. Poor filtration and treatment may compromise ground water quality.

Many of the dominant soil types in the study watersheds have severe limitations for septic suitability (Table 8). Geologic conditions in many parts of the diffuse moraine deposits are not likely to promote satisfactory septic system function resulting in surface and groundwater pollution. Although no septic inspections or sampling were conducted as part of this study, stream water quality sampling does not rule out improperly functioning systems as a possible cause of surface water pollution in the watersheds particularly in samples where *E. coli* concentrations during stormwater runoff exceeded 5,000 col/100ml. However, manure spreading for fertilizer is a common practice in the study area, and runoff from fields where manure has recently been spread can result in elevated stream *E. coli* levels as well.

To address these issues and concerns, development should proceed with caution especially in soils unsuited for conventional treatment systems. Competent soil scientists that are familiar with conditions should evaluate potential development sites for evidence of poor water movement, soil development, or filtering ability. Alternative technology, like the mound system, the at-grade system, the pressure-dosed system, or wastewater wetlands may provide a solution in soils that are unsuitable. Some soils may be suitable for alternating field technology which requires that a second field be available to accept effluent while the primary field "rests". Enlarged septic fields should be installed to increase the area of absorption. It is important to note, however, that some soils are too wet, too shallow, too impermeable, too steep, or too well-drained for any type of system.

Once the proper technology has been installed, proper maintenance is very important. Depending on the size of the system and the loading to it, systems should be cleaned out every 2-5 years. Property owners should divert surface runoff away from absorption fields, keep a cover of vegetation over the field, and keep foot and vehicular traffic over the field to a minimum. Pressure on septic systems can also be reduced by common water conservation practices like shorter showers and less flushing and rinsing within reason.

Soil Discussion and Summary

The type of soils in a watershed and the land uses practiced on those soils can impact the quality of the water leaving the watershed. Highly erodible land is concentrated primarily in the higher areas of the watershed furthest from the mouth. The Solomon Creek Headwaters and Solomon Creek West Subwatersheds contain the most HEL per unit of watershed acreage. Soil erosion contributes sediment to the rivers reducing water quality downstream and interfering with aquatic habitat and recreational uses. Nutrients attached to eroded soils fertilize and increase aquatic production. Additionally, soil eroding from the landscape silts in ditches and drainageways necessitating costly dredging maintenance projects. Not only does the sediment hinder water conveyance, it also provides a nutrient-rich substrate for rooted aquatic plant growth. Nutrients and nutrient-rich sediment can promote the growth of nuisance levels of algae and plants downstream in other waterbodies. Consequently, conservation methods and best management practices (BMPs) should be utilized when soils are disturbed in these areas. This includes residential development and farming practices in highly erodible soils.

Soil type should also be considered in siting septic systems. Some soils do not provide adequate treatment for septic tank effluent. Much of the land in the study watersheds is mapped in soils that rate as severely limited or generally unsuitable for use as septic tank absorption fields. This is typical for much of Indiana, as research by Dr. Donald Jones suggests that 80% of the soils in Indiana are unsuitable for wastewater treatment (Grant, 1999).

Pollution from septic tank effluent can affect waterways, the life it supports, and its users in a variety of ways. It can contribute to eutrophication (overproduction) and water quality impairment of lakes and other waterbodies in the watersheds. In addition, septic tank effluent potentially poses a health concern for users of both surface and groundwater in the watersheds. Swimmers, anglers, or boaters that have body contact with contaminated water may be exposed to waterborne pathogens. This is an issue of concern for Solomon Creek, its tributaries, and its receiving waterbody the Elkhart River, since according to Indiana State statutes, these waterbodies should support contact recreation as a beneficial use (IDEM, 2000; IAC, 2000). Fecal contaminants can be harmful to humans and cause serious diseases, such as infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illness. Additionally, nitrogen and pathogens may also leach into the groundwater compromising well water for drinking.

Land Use

Table 9 and Figure 7 present land use information for the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. Land use data was obtained from USGS EROS Data Center coverages. This data was generated using remote sensing techniques and in some areas was field checked. Data was last corrected to reflect current conditions in the watershed during October 2001. Land use data for each subwatershed is presented in Appendix 1.

TABLE 9. Land use in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

Land Use	Area (acres)	Area (ha)	Percent of Watershed
Open Water	49.6	20.1	0.14%
Low Intensity Residential	77.1	31.2	0.21%
High Intensity Residential	17.1	6.9	0.05%
High Intensity Commercial/Industrial/Transport	40.9	16.6	0.11%
Deciduous Forest	2,267.2	917.9	6.26%
Evergreen Forest	4.2	1.7	0.01%
Mixed Forest	0.4	0.2	<0.01%
Pasture/Hay	3,322.5	1,345.1	9.17%
Row Crops	29,577.6	11,974.7	81.62%
Other Grasses (Urban, Rec., Parks)	23.7	9.6	0.07%
Woody Wetlands	675.9	273.6	1.87%
Emergent Herbaceous Wetlands	183.2	74.2	0.51%
Total	**36,239.4**	**14,671.8**	**100%**

Approximately 91% of the watershed is used for agricultural purposes, including cropland, pasture, and agricultural woodlots. Eighty-one percent is used for row crop production. This percentage is slightly greater than that estimated by the U.S. Census of Agriculture (1997) for Elkhart (62%), Kosciusko (72%), and Noble (69%) Counties. Because the watershed is located in a rural area, more land is used for cultivation than is average for the counties. Table 10 contains more detailed U.S. Census of Agriculture (1997) data for the three counties.

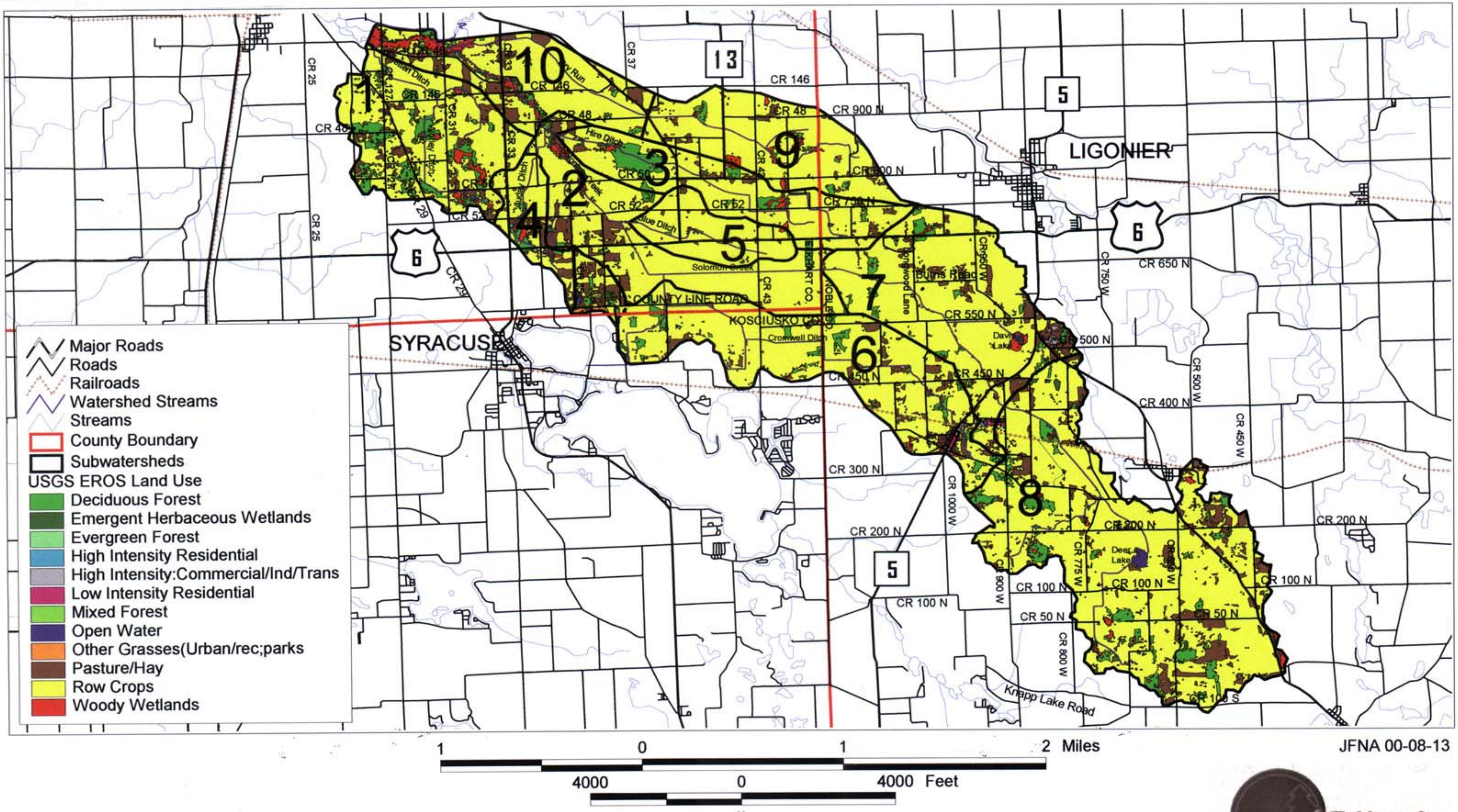


FIGURE 7. Land Use and Land Cover.

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TABLE 10. Detailed 1997 U.S. Census of Agriculture data for Elkhart, Kosciusko, and Noble Counties.

County	# of Farms	Land in Farms (acres)	Total Land (acres)	Percent of County Farmed
Elkhart	1,335	182,800	296,856	62%
Kosciusko	1,130	246,900	344,012	72%
Noble	942	182,000	263,125	69%

Source: U.S. Census of Agriculture, United States Department of Commerce (1997).

In general, row crop agriculture dominates land use throughout the subwatersheds (Figure 8). The Mouth Subwatershed is the most diverse with respect to different types of land use while Blue Ditch Subwatershed is the least diverse. The Meyer/Cromwell Subwatershed contains the only notable acreage of urban land use due to the municipality of Cromwell.

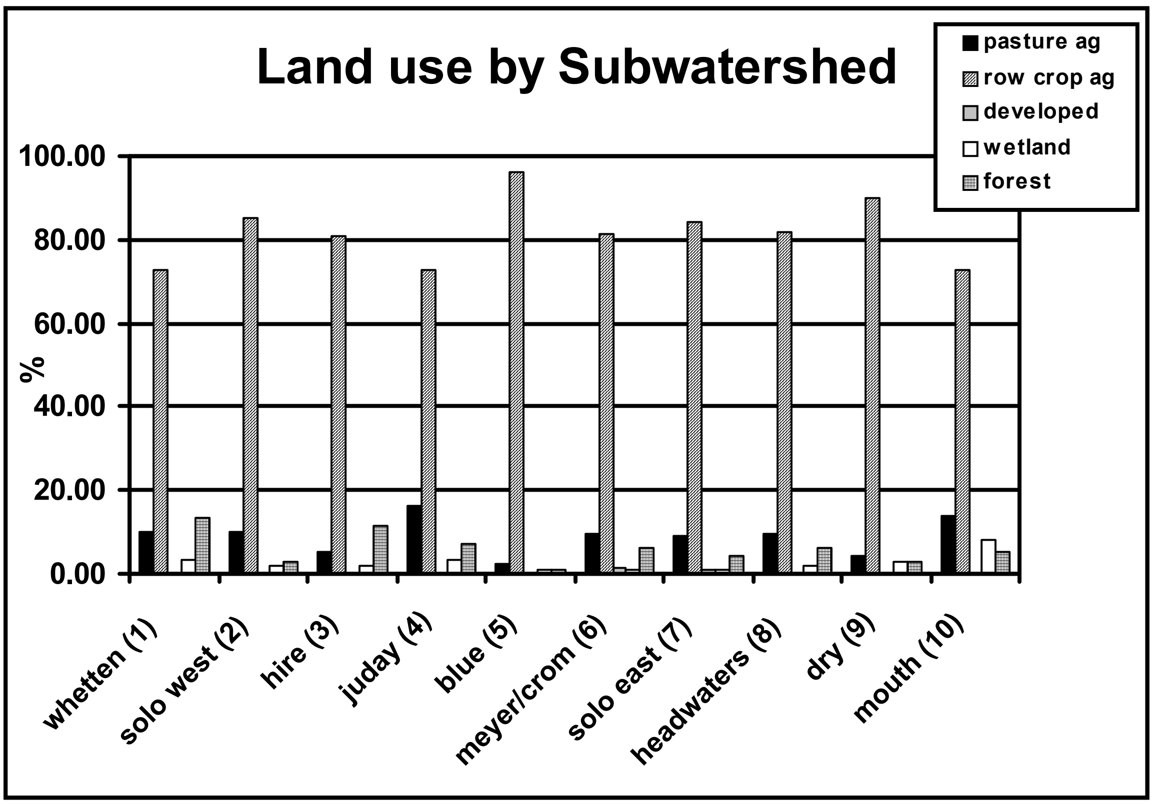


FIGURE 8. Percent of total subwatershed area used for the broad land use categories: pasture agriculture, row crop agriculture, urban, wetland, and forest.

Aside from agricultural uses, forests and wetlands represent the only other notable land use within the study watershed (Figure 8). In some cases like along the mainstem of Solomon Creek in Subwatersheds 2 and 10, these wetland natural areas directly border stream segments. Not only do these forest areas and wetlands help moderate stream water temperature and velocity, they also offer water storage capacity and sediment and nutrient filtration. Figure 9 further classifies the wetlands based on National Wetland Inventory (NWI) data. According to the NWI data, most wet areas are palustrine, emergent wetlands (Table 11). Due to the small remaining

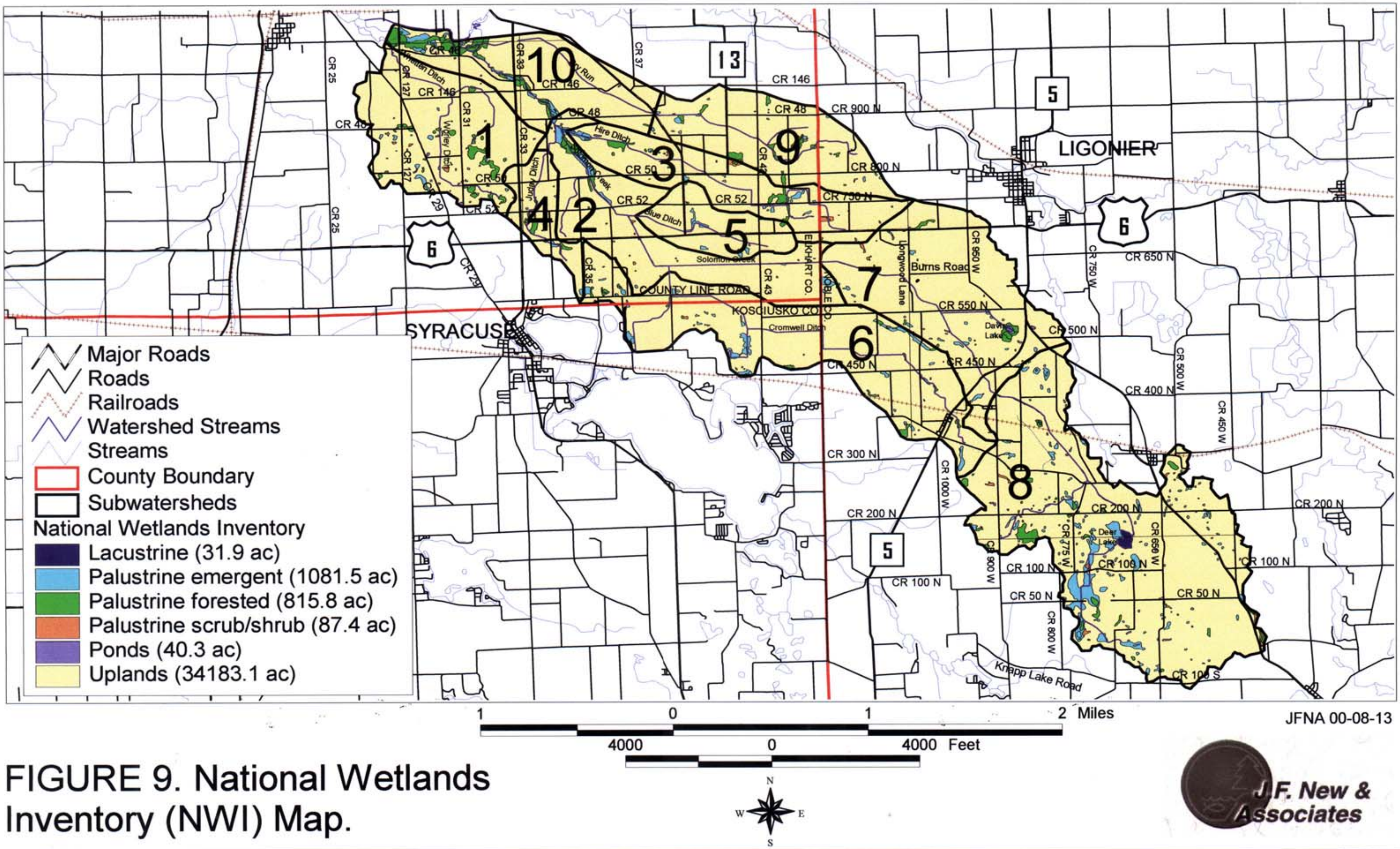


FIGURE 9. National Wetlands Inventory (NWI) Map.

concentration of forest and wetland land use (only about 12% of the watershed) their protection is merited. Farmers should also be encouraged to route drainage tiles toward specified treatment wetlands or filter areas. Riparian buffer area filtration is drastically reduced when drainage tiles completely bypass them, carrying drainage waters directly to the ditch.

TABLE 11. National Wetland Inventory (NWI) data for the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

Wetland Type	Area
Lacustrine	31.9 acres (78.8 ha)
Palustrine emergent	1,081.5 acres (437.9 ha)
Palustrine forested	815.8 acres (330.3 ha)
Palustrine scrub/shrub	87.4 acres (35.4 ha)
Ponds	40.3 acres (16.3 ha)
Uplands	34,183.1 acres (13,839.3 ha)

Very few tracts of pastureland directly border streams in the watershed (Figure 7). Most notably, the Solomon Creek West Subwatershed contains some pastureland tracts that border the creek and one of its tributaries. When pastured livestock is allowed direct access to streams, pastureland use is closely coupled with riparian area degradation and increased soil, nutrient, and bacterial runoff. Efforts should be made to exclude livestock from waterways in these critical areas.

Other land uses are very negligible within the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. Open water, consisting of small ponds, occupies 0.07% of the watershed. Only 0.33% of the watershed has undergone urban development. The remaining land uses and coverage compose a meager 0.10% including non-vegetated developed land and sparse vegetated point bar and shoreline areas.

Soybeans, corn, small grains, and forage are the major crops grown in Elkhart, Kosciusko, and Noble Counties. Although exact percentages of each crop were not recorded for the study watershed, between 33-46% of the agricultural fields in the counties were planted with soybeans and 45-54% in corn in 2001 (Purdue University Cooperative Extension Service, 2001). It is likely that the study watersheds closely mirror these percentages. Table 12 contains more detailed information regarding percentage and acreage of Elkhart, Kosciusko, and Noble County fields used to produce different crops and commodities and estimated numbers of cattle in 2001. Note that Elkhart County ranks first in the state for dairy cattle production; however, Jeff Burbrink of the Elkhart County Purdue Cooperative Extension Agency stated that the highest concentration of dairies and other animal operations in the county was not located in the study area (personal communication).

TABLE 12. Percent and acreage of Elkhart, Kosciusko, and Noble County fields with indicated present crop for year 2001. Percentages are taken from a field sampling of points along transects across the counties. No data are available for percent or acreage of land in permanent pasture. The number of beef cattle, dairy cattle, and total cattle in the counties in 2000 are also given. The last column provides production rank for each county in the state for each of the commodities.

Crop/Commodity	Percent or Number	Acreage of Land	Rank in State
Elkhart County			
Soybeans	33%	46,900	63
Corn	45%	60,800	61
Small Grains	4%	2,800	60
Hay/Forage	17%	21,200	5
Beef Cattle	1,900		43
Dairy Cattle	21,400		1
Total Cattle	39,200		1
Kosciusko County			
Soybeans	46%	86,700	17
Corn	48%	97,400	23
Small Grains	4%	5,000	34
Hay/Forage	1%	10,500	20
Beef Cattle	2,600		33
Dairy Cattle	3,500		10
Total Cattle	19,500		9
Noble County			
Soybeans	46%	61,800	50
Corn	54%	60,900	57
Small Grains	2%	5,700	35
Hay/Forage	5%	12,400	9
Beef Cattle	1,900		45
Dairy Cattle	5,100		7
Total Cattle	14,300		17

Source: Purdue Cooperative Extension Service, 2000 and U.S. Census of Agriculture, 2000.

Prime farmland is one of several land types classified and recognized by the USDA. Prime farmland is land that is best suited for crops. The land is used for cultivation, pasture, woodland or other production, but it is not urban land or water areas. This type of land produces the highest yields with minimal inputs of energy and economic resources. Farming it results in the least damage to the environment. Therefore, when possible, the optimal land use strategy places industrial and residential development on the marginal lands while keeping prime farmland available for production. According to the USDA soil survey of Kosciusko County, approximately 65% of the acreage in the general area meets prime farmland requirements, and the majority of the land in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds is classified as prime farmland.

"A recent trend in land use in some parts of the county has been the loss of some prime farmland to industrial and urban uses. The loss of prime farmland to other uses puts pressure on marginal lands, which generally are more erodible, wet or droughty, and less productive and cannot be as easily cultivated." (Staley, 1989). Cultivation of more marginal land also results in more damage to the environment. Although neither the Whetten Ditch, Solomon Creek, nor the Dry Run Watersheds are undergoing rapid urbanization, some new development was noted during the windshield tour (which will be discussed in more detail later). This type of change in land use will have obvious impacts on water quality, especially if it results in more farming of marginal land. Again, careful land use and development planning can minimize the need to produce crops on compromised land.

Agricultural Best Management Practices (BMPs)

Approximately 87% of the Whetten Ditch, Solomon Creek, and Dry Run Watersheds is utilized for agricultural row crop production. This land use, particularly on highly erodible soils and in other environmentally sensitive areas, can have an impact on water quality downstream. Runoff from farm fields can contain a variety of pollutants including nutrients (nitrogen and phosphorus), herbicides, pesticides, sediment, and bacteria (*E. coli*). In addition, the original creation of agricultural land involved draining low wet areas using tiles and ditches. This has decreased the storage capacity of the land and increased peak flows in streams and channels in the watersheds. An increase in both the volume and velocity of peak flows typically leads to increases in land erosion and ultimately increases in sediment and sediment-associated particle loading to the receiving waterbody. According to the National Research Council (1993), non-point source pollution by contaminants in agricultural runoff is a major cause of poor surface water quality in the USA.

Several programs and Best Management Practices (BMPs) have been developed to address non-point source pollution associated with agriculture. BMPs may be structural or managerial in nature (Osmond et al., 1995). Filter strips, riparian buffer strips, grassed waterways, and use of erosion control structures are examples of structural practices, while rotational grazing, conservation tillage, and nutrient and pesticide management, are managerial BMPs. Each is aimed at conservation to help ensure healthy and productive farmland while protecting sensitive areas on the landscape. Programs and BMPs that are currently in use in the study watersheds or that could potentially be used more frequently or consistently are discussed below.

The Conservation Reserve Program

Introduction

The Conservation Reserve Program (CRP) is the single, largest environmental improvement program offered by the federal government. The program arose out of concerns raised by USDA studies conducted in the early 1980s showing that the nation's cropland was eroding and losing soil at a rate of 3 billion tons per year (USDA, 1997). The CRP provides volunteer participants with an annual per-acre rent and 50% of the cost of establishing permanent land cover. In return, participants are required to retire the cropland from production for 10-15 years.

Removing land from production and planting it with vegetation has a positive impact on water quality within the given watershed. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that lakes within ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores. A lower TSI is indicative of lower productivity and better water quality.

The New Conservation Reserve Program established in 1997 is targeted at enrolling the most environmentally sensitive land into the program. The program was capped by Congress at 36.4 million acres, meaning that only about 15% of eligible cropland could be enrolled. Land is evaluated and scored for environmental benefit, including: wildlife habitat enhancement, water quality benefits, reduced erosion, long-term retention benefits, air quality benefits, land's location in a Conservation Priority Area, and cost of enrollment per acre. The CRP attempts to maximize conservation and economic benefits by focusing on highly erodible land, riparian areas, cropped wetlands, and cropland associated with wetlands.

CRP in the Study Watersheds

A variety of conservation practices are currently in use in the study watersheds. Figure 10 shows the locations of cropland enrolled in the CRP and the years when the tracts will be released from the program. (Please note that some tracts were listed with release dates of 1998, 1999, and 2000. It is not known if these tracts are still enrolled in the CRP. For this analysis, it was assumed that these areas are currently enrolled.) Instead of farming the tracts, landowners have installed filter strips, grassed waterways, and wildlife set-asides. Table 13 contains acreages of land enrolled in the CRP. The largest of the study area subwatersheds, Solomon Creek Headwaters, contains the largest acreage currently enrolled in the CRP. Only two other watersheds, Solomon Creek East and Meyer Cromwell Ditch Subwatersheds participate in the CRP. Of the subwatersheds with land currently enrolled in the program, <2% of the total land area is classified as CRP.

TABLE 13. Acreages of land enrolled in the CRP by subwatershed.

Subwatershed	Acres	Hectares	Percent of Watershed	HEL:CRP
Whetten Ditch	0	0	0%	175:0
Solomon Creek West	0	0	0%	134:0
Hire Ditch	0	0	0%	0:0
Juday Ditch	0	0	0%	0:0
Blue Ditch	0	0	0%	0:0
Meyer/Cromwell Ditch	1.4	0.6	0.03%	6881:1
Solomon Creek East	39	15.8	0.83%	232:1
Solomon Creek Headwaters	100	40.5	1.08%	27:1
Dry Run	0	0	0%	43:0
Mouths of Solomon Creek and Dry Run	0	0	0%	0:0
Total	**140.4**	**56.9**	**0.39%**	**24:1**

Source: Farm Service Agencies of Elkhart, Kosciusko, and Noble Counties.

A comparison of CRP set-asides and HEL designations can help to determine areas where management may be best targeted. Some CRP set-asides within the study watersheds overlap with land that is highly erodible (Figure 10); however, some watersheds contain HEL but not CRP. The small acreages of HEL (<200 acres) within the Whetten Ditch, Solomon Creek West,

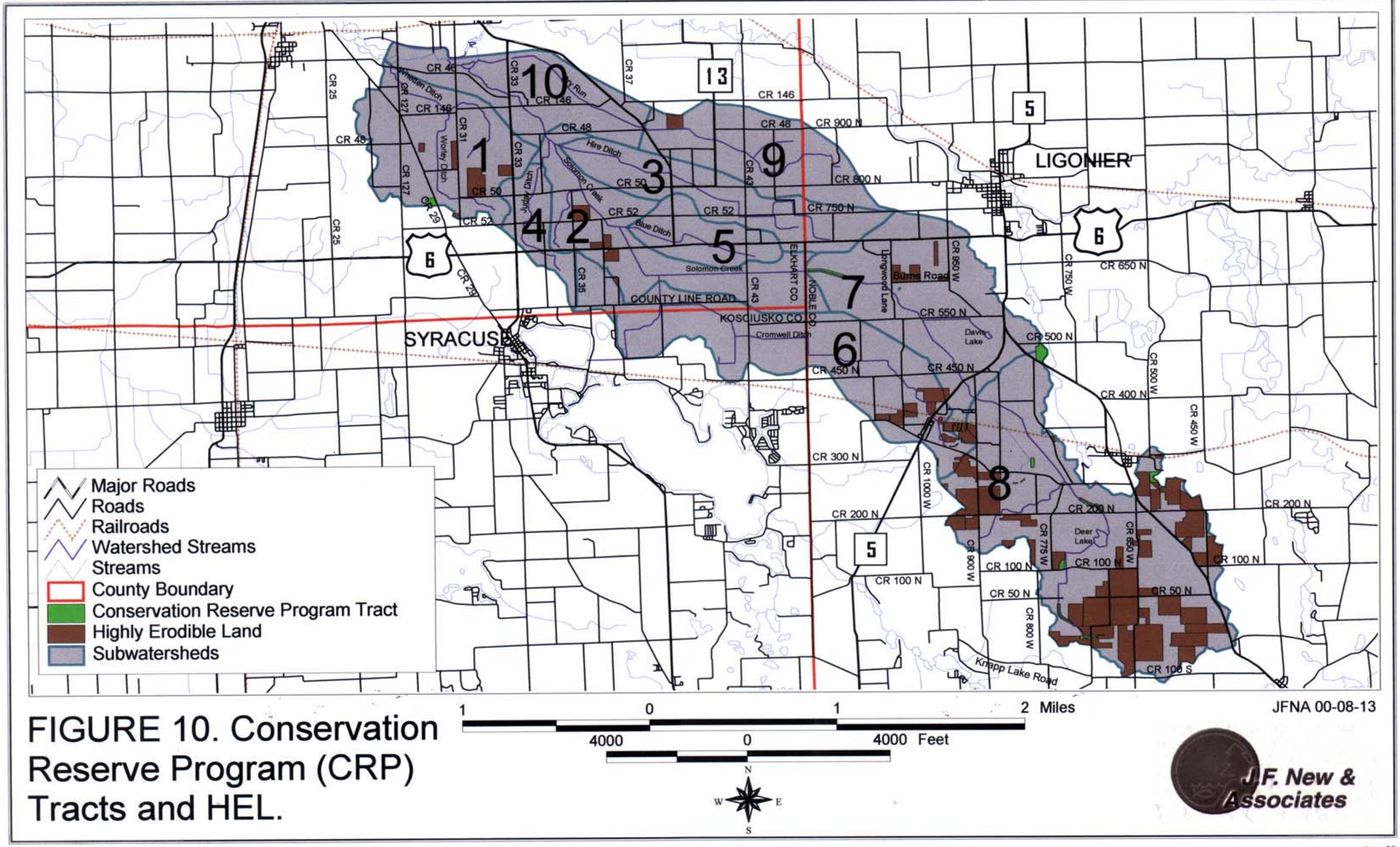


FIGURE 10. Conservation Reserve Program (CRP) Tracts and HEL.

and Dry Run Subwatersheds are not treated with any CRP enrollment. Hire Ditch, Juday Ditch, Blue Ditch, and the Mouth Subwatersheds contain no HEL and also no CRP. Of the subwatersheds containing both HEL and CRP, the Solomon Creek Headwaters has the lowest HEL:CRP ratio, while the Solomon Creek East Subwatershed has the highest (6881:1). This means that for every 6881 acres of HEL, only one acre is designated CRP. Future CRP enrollment efforts should focus on the HEL within the Meyer/Cromwell Ditch, Solomon Creek East, and Whetten Ditch Subwatersheds.

Some non-protected HEL tracts directly border streams and tributaries to streams within the watershed. HEL tracts that adjoin streams are located in the Whetten Ditch, Meyer/Cromwell Ditch, Solomon Creek Headwaters, and Dry Run Subwatersheds. These tracts would be optimal sites for CRP or other program enrollment.

Conventional Structural Conservation Practices

Introduction

Continuous sign-up is permitted through the CRP for special high-priority conservation practices that lead to significant environmental benefits. These practices are structural in nature and are specially designed to protect and enhance wildlife habitat, improve air quality, and improve waterway condition. These conservation practices and relevant research involving their use are discussed in more detail below.

Filter Strips

A filter strip is an area of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants from runoff. Filter strips slow the velocity of water, allowing settling of suspended particles, infiltration of runoff, adsorption of pollutants on soil and plant surfaces, and uptake of soluble pollutants by plants. Slower runoff velocities and reduced flow volumes lead to decreased downstream erosion.

A modeling study by Texas A&M University suggests that if filters were properly installed in all appropriate locations, sediment delivery to rivers and lakes could be reduced by two-thirds (National Conservation Buffer Council, 1999). Preventing sediment delivery to streams has important and significant economic ramifications. According to a study by the Ohio State University Extension Service, a 25% decrease in the amount of sediment entering waterways in the state would save $2,700,000 in water treatment costs per year (Leeds et al., 1997). The cost of dredging sediment out of these waterways was estimated at $1,500,000 per year for the state of Ohio. Additionally, buffer strips have been associated with healthier aquatic communities (Wiegel et al., 2000).

Typically, filter strips are planted on cropland at the lower edge of a field or adjacent to waterways. They are most effective when receiving shallow, uniform flow rather than concentrated runoff localized in channels or gullies. The Natural Resources Conservation Service (NRCS) recommends minimum filter strip widths based on intended purpose of the area (NRCS, 2000). The minimum flow length is set at 20 ft (6 m), but the minimum can be increased to 30 ft (9 m) based on sediment, particulate organic matter, and sediment-adsorbed contaminant loading in runoff. The average watershed slope above the filter strip must be greater than 0.5% but less than 10%. The NRCS standard is site-specific with plans and specifications required for each field site where a filter strip will be installed. It is important to keep in mind that effective filter strip width is also dependent on the amount of land draining into the filter. Ratios of the field drainage area to the filter area should be no greater than 50:1. Based on a survey of more than 2,700 CRP sites in the U.S., the ratio averaged approximately 3:1 (Leeds et al., 1993).

A wide variety of vegetation types have been used for planting filter strips. The ideal plant or combination of plants would be characterized as: native to Indiana, sod-forming, palatable as forage, somewhat cool season so as to grow early in spring when most runoff events occur, hardy, rapidly growing, tolerant of nutrient-poor conditions so as to not need fertilization, able to remain standing throughout the winter providing shelter for wildlife, and economical/affordable.

The use of plants native to Indiana is ecologically the most desirable alternative. (Please see the NRCS Conservation Practice Standard Code 393 for specifics and requirements regarding vegetation planting within filter strips (NRCS, 2000).) Advantages of planting native vegetation include: 1.) native species possess extensive rooting structures that hold soil and reduce erosion (Figure 11 depicts rooting depths of several native grass species); 2.) many types can be hayed for forage use, and in fact big bluestem and Indian grass as highly palatable for forage (Clubine, 1995); 3.) natives are hardy and able to withstand various hydrologic regimes; 4.) low maintenance and cost over the long-run due to natural re-seeding processes and hardiness; 5.) low nutrient demand so as to not require costly fertilization which can further impair water quality; 6.) native plants provide wildlife habitat by remaining standing through the winter; 7.) native wildflowers are beautiful, and their seeds can be added to mixes for aesthetic value; 8) some legume species like roundhead lespedeza, the prairie clovers, lead plant, and tickclovers are quite resilient to livestock grazing (Clubine, 1995).

Some disadvantages of establishing native herbaceous vegetation in filter strips also exist: 1.) most native grasses are warm season (except for red top and Virginia wild-rye) and may not offer optimal nutrient uptake in early spring when many runoff events occur; 2.) some species have been reported to be difficult to establish and may take years for full stand development (Leeds et al., 1993); 3.) native wildflower plants and other forbs can be quite susceptible to herbicides used in crop production; 4.) many are quite expensive to produce (see tables below); 5) some native legume species like Illinois bundleflower have been shown to be susceptible to grazing (Clubine, 1995).

The following Tables 14-20 present lists of recommended native cool season grasses, legumes, and wildflowers. Information is also presented on species that are considered less than desirable as filter strip vegetation. Five different recommended mixes are provided along with seeding rates in lbs/acre and approximate costs according to the February of 2001 price listing of Sharp Bros. Seed Company of Missouri and the J.F. New Native Plant Nursery 2001 Wholesale Catalogue. Mixes should be chosen based on management application and available finances. Table 21 lists vegetation types that should not be used due to severe limitations. It is important to remember that a filter strip or conservation easement planted with any vegetation type is better than not having the easement at all. Even if optimal mixes are not chosen or applied, an individual's participation in a set-aside program will have positive effects for water quality.

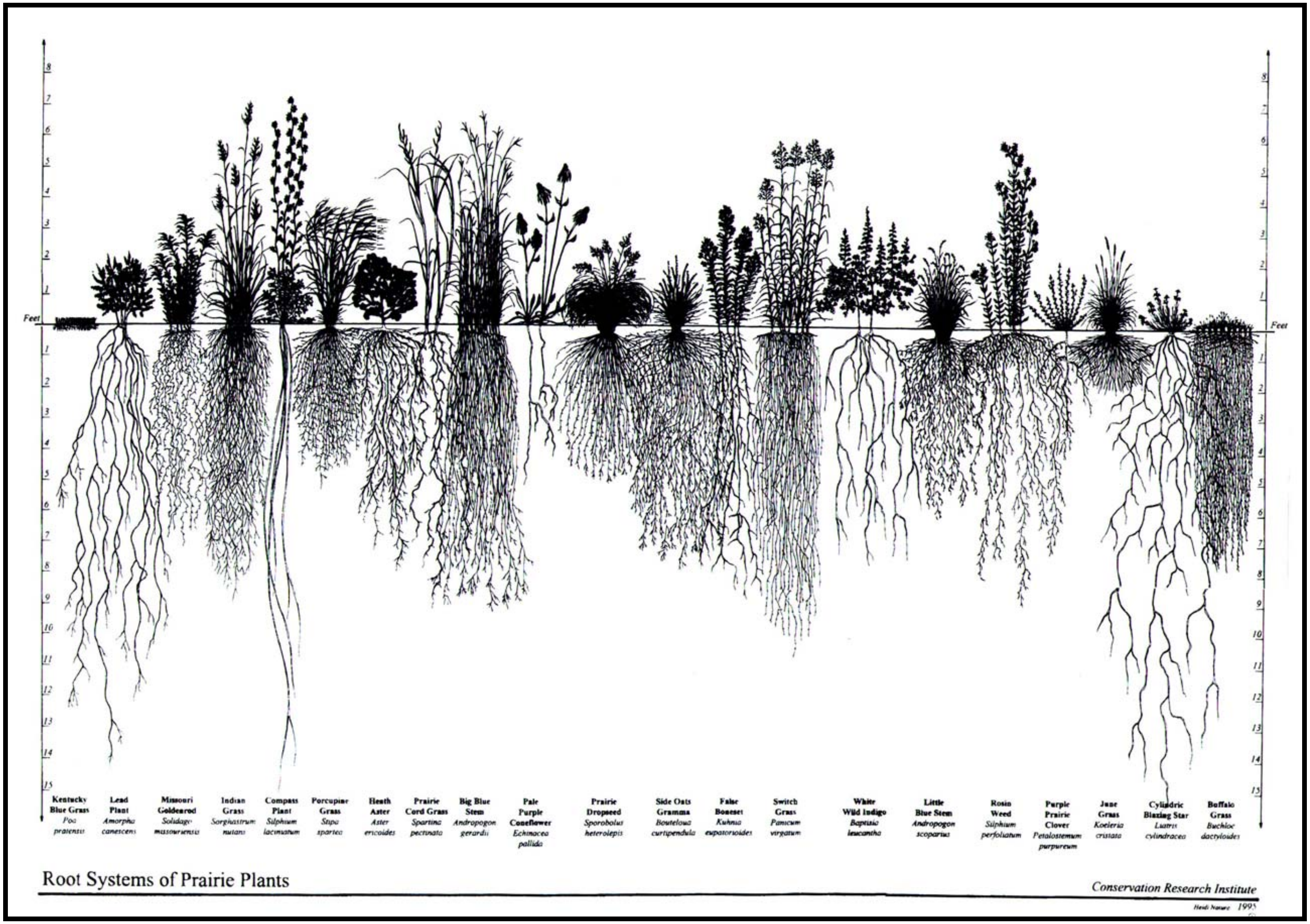


FIGURE 11. Rooting Depths of Native Grasses and Forbs.

It is also necessary here to caution landowners who receive federal and/or state monies for planting vegetation. Certain programs may require special seeding mixtures. For example, CRP filter strips must be planted as per Tables 1 and 2 in the NRCS Conservation Practice Standard Code 393. The following eight tables give recommendations for landowners who may be purchasing their own seed or have received cost-share monies from programs that are more flexible with respect to seeding requirements.

TABLE 14. Recommended native cool season grass species and seeding rates (lbs/acre) for filter strip planting with price/lb per Sharp Bros. Seed Company of Missouri as of February, 2001.

Species	Seeding Rate	Price/lb
Red top	4 lbs/acre	$3.40
Virginia wild-rye	4 lbs/acre	$6.90

* If seeding both together, use 2.5 lbs/acre of each.

TABLE 15. Recommended native legume species and seeding rates (lbs/acre) for filter strip planting with respective prices/lb.

Species	Seeding Rate	Price/lb
Roundhead lespedeza	0.25 lbs/acre	$98.00
Partridge pea	0.25 lbs/acre	$16.10
Illinois bundleflower	0.25 lbs/acre	$6.90
Purple prairie clover	0.25 lbs/acre	$23.00

* These forbs should be sown with native grass seed mixture.

TABLE 16. Recommended native wildflower species for filter strip planting with respective prices/lb.

Species	Price/lb
Black-eyed susan	$22.50
Lanceleaf coreopsis	$27.00
White prairie clover	$137.50
Ashy sunflower	$55.50
Pale purple coneflower	$108.90
Pitcher sage	$72.00
Compass plant	$99.00
Rosinweed	$74.25
Leadplant	$99.00
Purple coneflower	$29.70
Rattlesnake master	$99.00

* These native wildflowers can be seeded in small quantities (<0.25 lbs/acre) along with recommended seeding of native grasses.

TABLE 17. Optimal seed mix for filter strip seeding. This mix is considered optimal based on water quality and soil protection benefits, habitat management benefits, and economy/affordability. Six species are included plus a mix of wildflowers for a total seeding rate of 5.25 lbs/acre.

Species	Seeding Rate
Big bluestem	1.3 lbs/acre
Indiangrass	1.5 lbs/acre
Little bluestem	1.5 lbs/acre
Sideoats grama	0.5 lbs/acre
Switchgrass	0.2 lbs/acre
Mixed wildflowers	0.25 lbs/acre
TOTAL PRICE	**$64.25/acre**

*** Virginia wild-rye and red top can be seeded with the above mixture to increase cool season growth. Virginia wild-rye should be seeded at 1 lb/acre and red top at 2 lbs/acre.**

TABLE 18. Economy mix for filter strip seeding. This mix also offers native grass species at a more affordable cost. Only three species are included for a total seeding rate of 4.0 lbs/acre.

Species	Seeding Rate
Big bluestem	1.0 lbs/acre
Indiangrass	1.0 lbs/acre
Little bluestem	2.0 lbs/acre
TOTAL PRICE	**$49.90/acre**

*** Virginia wild-rye and red top can be seeded with the above mixture to increase cool season growth. Virginia wild-rye should be seeded at 1 lb/acre and red top at 2 lbs/acre.**

TABLE 19. Ultra economy mix for filter strip seeding. This mix offers only one native grass species at the most affordable cost. It is recommended that Virginia wild-rye and red top be seeded with the switchgrass to increase species and habitat variety and to increase cool season growth in the filter strip.

Species	Seeding Rate
Switchgrass	5 lbs/acre
TOTAL PRICE	**$15-20 lbs/acre depending on variety selected**

TABLE 20. Wildlife habitat management seed mix for filter strip planting or for other areas where managing prairie-type habitat for wildlife is desirable. The total cost for 51.5 lbs for seeding of one acre is $450.00 (J.F. New Native Plant Nursery Wholesale Catalogue, 2001). The temporary grasses serve only to stabilize soils and provide habitat until the permanent, perennial grasses fully develop.

Species	Seeding Rate
Permanent Grasses	5 lbs/acre
Big bluestem	
Little bluestem	
Sideoats grama	
Virginia wild-rye	
Switchgrass	
Temporary Grasses	44 lbs/acre
Seed oats	
Annual rye	
Timothy grass	
Native Forbs	2.5 lbs/acre
Butterfly milkweed	
New England aster	
Partridge pea	
Sand coreopsis	
Purple coneflower	
False sunflower	
Rough blazing star	
Wild lupine	
Yellow coneflower	
Black-eyed susan	

TABLE 21. Plant species that are generally not good candidates for use in filter strips and reasons for their unsuitability.

Species	Reason for Insuitability
Birdsfoot trefoil	poor rooting structure with little ability to stabilize soil
Smooth brome	poor rooting structure with little ability to stabilize soil
Fescue	poor rooting structure with little ability to stabilize soil
Japanese millet	poor rooting structure with little ability to stabilize soil
Orchardgrass	poor rooting structure with little ability to stabilize soil
Reed canarygrass	poor rooting structure with little ability to stabilize soil; invasive; excludes other more beneficial vegetation; no wildlife habitat benefit
Crownvetch	poor rooting structure with little ability to stabilize soil; invasive
Kentucky bluegrass	very shallow root system; invasive; excludes other more beneficial vegetation; no wildlife habitat benefits
Perennial rye	invasive; excludes other more beneficial vegetation
Red clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive
White clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive

Filter strip effectiveness has been the subject of voluminous recent research. Most research indicates that filter strips are effective at sediment removal from runoff with reductions ranging from 56-95% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999). Most of the reduction occurs within the first 15 feet (4.6 m). Smaller additional amounts are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrient concentration like those of nitrate, dissolved phosphorus, atrazine, and alachlor, although reductions of up to 50% have been documented (Conservation Technology Information Center, 2000). Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Filter strip age is an additional factor of importance for effective function. Schmitt et al. (1999) found older grass plots (25 yr-old) to be more effective filters than recently planted ones (2 yr-old). A longer amount of time was required for runoff to reach the outfall of the older plots, suggesting that a strip's ability to slow runoff and filter pollutants increases with age.

Filter strips are effective in reducing sediment and nutrient runoff from feedlot or pasture areas as well. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen, and approximately 67% of the phosphorus from feedlot runoff. In addition, they found a 67% reduction in runoff volume. However, it is important to note that filter strips should be used as a component of an overall waste management system and not as a sole method of treatment.

Filter strips, like all conservation practices, require regular maintenance in order to remain effective. Maintenance consists of: 1) inspection of the project frequently, especially after large storm events; 2) repairing and reseeding of any areas where erosion channels develop; 3) reseeding of bare areas; 4) mowing and removing hay to maintain moderate vegetation height while not mowing closer than 6 inches. To avoid destruction of wildlife nesting areas, delay mowing until after mid-July; 5) controlling trees, brush, and noxious or invasive weeds within the filter; 6) applying fertilizer and lime at rates suggested by regular soil testing.

Riparian Buffers

In many ways similar to filter strips, riparian buffers are streamside plantings of trees, shrubs, and grasses intended to intercept pollutants before they reach a river or stream. Although comparisons reveal that riparian buffers are no better than grassed strips at retaining nutrients and sediment, they offer shade and cover to the stream, thereby providing valuable fish and wildlife habitat (Daniels and Gilliam, 1996). Due to their deeper rooting systems, riparian buffers can filter both surface and subsurface runoff before it reaches the waterway. The rooting systems of riparian buffers can also serve to stabilize banks and soils especially along ditches that pass through mucky or easily erodible soil.

Field Borders

Field borders are 20-ft wide filter strips or bands of perennial vegetation planted at the edge of fields that can be used as turning areas for machinery. They also provide wildlife cover, protect water quality, and reduce sheet, rill, and gully erosion. Borders should be repaired and reseeded after storms and should be mown and harvested in late summer to early fall to encourage growth for the next spring.

Shelterbelts/Windbreaks

Shelterbelts are rows of trees, shrubs, or other vegetation used to reduce wind erosion and protect crops while also providing protection for wildlife, livestock, houses, and other buildings. Similar to shelterbelts, windbreaks or hedgerows are located along crop borders or within fields themselves. Air quality improvement and wildlife habitat provision are the greatest benefits of these vegetation belts.

Grassed Waterways

Grassed waterways are natural or constructed channels that are seeded with filter vegetation and shaped and graded to carry runoff at a non-erosive velocity to a stable outlet and vegetated filter. Vegetation in the waterway protects the topsoil from erosion and prevents gully formation, while providing cover for wildlife. The stable outlet is designed to slow and spread the flow of water and direct it towards the vegetated filter.

Grassed waterways are typically used where water tends to concentrate, like in draws, washouts, or other low-lying gully areas. They can also be used as outlets from other conservation practices (like terraces) or in any other situation where a stable outlet and vegetated filter can be built and maintained.

These vegetated filter systems may be trapezoidal or parabolic in shape, but should be broad and shallow in construction. They should be able to carry the runoff of a 10-year storm event. The stable outlet should be planted with perennial, sod-forming grasses to provide a dense filter. The vegetated filter below the outlet should be constructed as a typical filter strip would be.

Proper operation and maintenance is necessary for effective grassed waterway function. Tillage and crop row direction should be perpendicular to the waterway to allow drainage and to prevent water movement along edges. Machinery crossing areas should be stabilized to prevent damage to the waterway. Vegetation within the filter should be protected from direct herbicide applications. Certain species may be more tolerant of certain herbicide chemicals. It is also important to keep the strip and its outlet as wide as is possible. The waterway may need reconstruction from time to time to maintain proper shape.

Shallow Water Areas

Shallow water areas within or near farmland provide cover and a water source for wildlife while also acting as a filter. Embankments and berms that pond water increase the land's water storage capacity helping to reduce volumes and flow rates of runoff. Constructed wetlands contribute to water quality improvement by: 1) reducing coliform bacteria by 90% (Reed and Brown, 1992); 2) fostering growth of microbes that recycle and retain nutrients (Wetzel, 1993); 3) providing additional adsorption sites for nutrients through the decomposition of organic matter (Kenimer et al., 1997); 4) providing anaerobic areas where denitrification processes can release nitrogen to the atmosphere; 5) degrading organic materials thereby decreasing biological oxygen demand (BOD); 6) offering sedimentation and filtration processes which remove suspended solids and adsorbed nutrients; and 7) providing flood water storage to attenuate peak flood flows. Potential sites for wetland restoration or construction will be discussed in the Aerial Tour and Windshield Survey Sections of this report.

Wellhead Protection Area

Wellhead protection areas help assure the quality of public water supplies drawn from wells. Continuous CRP enrollment is available for land within a 2000-ft radius of a public well. Vegetation planted in these areas can further help prevent water supply contamination.

Cover Crops

The use of cover crops, such as winter wheat prevents soil from being exposed through the winter and early spring months when some of the most pronounced runoff events may occur in Indiana. Cover crops reduce surface runoff by as much as 50% due to increased infiltration (Unger et al., 1998). Reductions in both the dissolved and particulate forms of nitrogen and phosphorus have also been documented.

Other Conventional Structural Conservation Practices

A wide variety of other conventional structural conservation practices have been prescribed and are in use in various areas of the county. Although not all practices are applicable in every situation, systems of two or more structural BMPs used in concert are often required to achieve the desired conservation benefit. A complete listing of the over 160 different conservation practices recognized by the USDA is available online at http://www.ncg.nrcs.gov/nhcp_2.html. The website offers standards and more details for each practice in a portable document format (PDF) and in MS-Word format. Structural conservation practices that are relevant for use in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds are listed in Appendix 2.

Conventional Managerial Conservation Practices

Introduction

Managerial BMPs are those that involve behavior or decisions made with respect to normal land use operation. Commonly used practices include conservation tillage, rotational grazing, and pesticide management. Managerial conservation practices are often less expensive because they don't involve building a structure; however, successful implementation may require a changing of habitual behaviors and some trial and error experimentation. Several commonly used managerial practices are discussed below.

Conservation Tillage

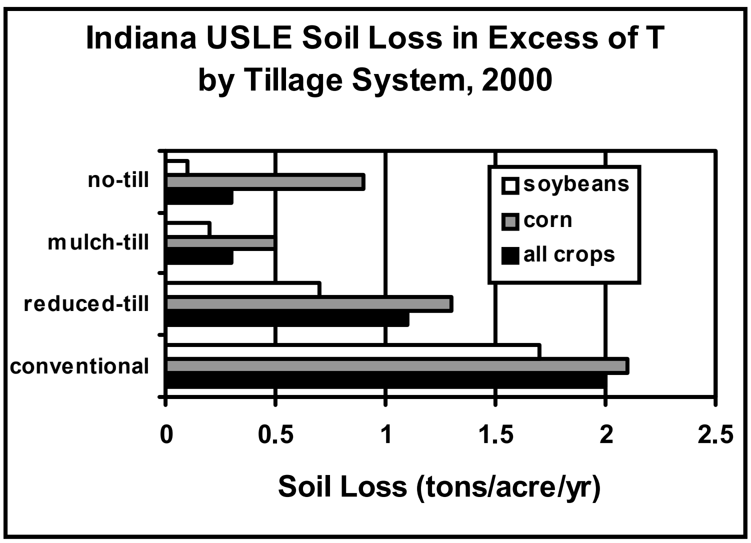
Introduction

Removal of land from agricultural production may not be economically feasible in some cases. Conservation tillage offers the potential for reducing erosion without removing the land from production. Conservation tillage is a crop residue management system that leaves at least one-third of the soil covered with crop residue after planting. Table 22 offers description of the different tillage types. No-till, ridge-till, and mulch-till are all examples of conservation tillage.

Aside from valuable time-saving for the producer, a comprehensive comparison of tillage systems shows that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (CTIC, 2000). Figure 12 illustrates calculations of soil loss with respect to the "tolerable" amount of soil that can be lost while still maintaining the productivity of the soil through natural formation processes. On average, all tillage methods exceed the T value for Indiana soils; however, soil loss is less using no-till and mulch tillage. Reductions in pesticide loading have also been reported (Olem and Flock, 1990). In his review of Indiana lakes, Jones (1996) documented lower Trophic State Index (TSI) scores in ecoregions with higher percentages of conservation tillage. (A TSI is a score that condenses lake water quality data into a single, numerical index. Higher scores indicate evidence of eutrophication (overproductivity) and poorer water quality.) No-till practices are also good for wildlife. North Carolina researchers have found that crop residues provide the food that quail chicks need to survive the first few weeks of life. Additionally, conservation tillage reduces carbon dioxide emissions from the soil. Carbon dioxide, the most ubiquitous of the greenhouse gases, is being found at ever-increasing concentrations in the atmosphere and has been linked to global warming.

TABLE 22. Tillage type descriptions.

Type	Description	% Remaining Residue	Conservation Tillage Type?
No-till/strip-till	soil is undisturbed except for strips up to 1/3 of the row width	>30%	Yes
Ridge-till	4-6" ridges are formed on strips up to 1/3 of the row width	>30%	Yes
Mulch-till	full width of the row is tilled using only one or two tillage passes	>30%	Yes
Reduced-till	full width of the row is tilled using multiple tillage passes	16-30%	No
Conventional-till	full width of the row is tilled using multiple tillage passes	<15%	No



Source: Clean Water Indiana Education Program, Purdue University.

FIGURE 12. Indiana average USLE soil loss in tons/acre in excess of T by tillage system for 2000. USLE is the Universal Soil Loss Equation. Values shown are in excess of T, which is the "tolerable" amount of soil that can be lost while maintaining the productivity of the soil. Most Indiana soils have a T-value of 3-5 tons per acre per year.

Agricultural economists with the Ohio State University Extension have reported that farmers adopting conservation tillage in the Maumee and Sandusky River Watersheds saw modest decreases in farm production costs (Agrinews, 2001). During that same time period, monitoring data showed decreased loading to Lake Erie of many non-point source pollutants that are related to farming. The researchers reported individual farm savings of 2-8% in labor costs and 6-15 percent in machinery operation costs; however, farmers adopting no-till practices did incur a 10-18% increase in herbicide costs due to lack of tillage for mechanical weed control.

While conservation tillage has been shown to reduce total phosphorus and total nitrogen in surface runoff by as much as 70 and 75% respectively, increased dissolved phosphorus and nitrate losses have been documented (Sharpley and Smith, 1994). In the Sharpley and Smith (1994) study, nitrate concentrations were increased from 4.5 to 29 mg/l and dissolved phosphorus concentrations were 300% higher. The increase in nitrate was attributed to increased infiltration that occurs with conservation tillage. Higher phosphorus concentrations were attributed to leaching of the nutrient from crop residue and preferential transport of smaller-sized soil particles that is associated with no-till practices. Another study by the Ohio State University Extension also documented 10-15% increases in nitrate runoff to local streams (Indiana Agrinews, 2001) and suggested that conservation tillage time savings allowed farmers to substitute winter wheat planting with corn, requiring higher amounts of nitrogen fertilizers.

Tillage Patterns in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds

While conservation tillage patterns were not estimated for the study watersheds, they are in use throughout Elkhart, Kosciusko, and Noble Counties and on many fields within the watersheds. Table 23 shows conservation tillage usage patterns in the growing season of 2001 for these counties.

TABLE 23. Percent (number) of crop fields with indicated tillage system in the growing season of 2001 for Elkhart, Kosciusko, and Noble Counties. N/A refers to those fields where tillage was not performed as in the second year or later of hay, fallow fields, and fields in CRP.

County	No-till	Ridge-till	Mulch-till	Reduced-till	Conventional-till	N/A
Corn						
Elkhart	13 (27)	0 (0)	15 (32)	41 (84)	31 (64)	0 (0)
Kosciusko	18 (42)	0 (0)	6 (15)	22 (52)	54 (126)	0 (0)
Noble	30 (61)	0 (0)	11 (21)	26 (52)	32 (65)	0 (1)
Soybeans						
Elkhart	37 (55)	1 (1)	30 (45)	21 (32)	11 (16)	0 (0)
Kosciusko	55 (125)	0 (0)	17 (38)	17 (38)	11 (25)	0 (0)
Noble	83 (141)	0 (0)	5 (9)	8 (14)	3 (5)	0 (0)
Small Grain						
Elkhart	0 (0)	0 (0)	0 (0)	6 (1)	6 (1)	88 (15)
Kosciusko	28 (5)	0 (0)	39 (7)	22 (4)	11 (2)	0 (0)
Noble	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Hay/Forage						
Elkhart	0 (0)	0 (0)	1 (1)	0 (0)	3 (2)	96 (73)
Kosciusko	2 (1)	0 (0)	0 (0)	2 (1)	4 (2)	2 (1)
Noble	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Fallow/Other						
Elkhart	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (8)
Kosciusko	0 (0)	0 (0)	0 (0)	33 (1)	67 (2)	0 (0)
Noble	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	25 (1)

Source: Purdue Cooperative Extension Service, 2001.

In Kosciusko County, the majority of the land used for corn production was conventionally tilled (Purdue Cooperative Extension Service, 2001). Producers in Elkhart and Noble Counties produced most of their corn and soybean crops using a conservation tillage method. While no-till was the most commonly used conservation tillage technique, mulch till and reduced till were also used with some frequency. In general small grains were grown in Elkhart and Kosciusko Counties on soils that were conservation tilled or not tilled. Little (if any) small grains were produced in Noble County. Due to the large dairy industry in Elkhart County, 76 fields were used for hay or other forage production, and 96% of those fields were not tilled at all. Of the 92 counties in Indiana, Elkhart County ranked 43rd and 67th for percent of corn and soybeans, respectively, planted using a no-till system in 2000 (Evans et al., 2000). Kosciusko County ranked 43rd and 62nd, and Noble County ranked 27th and 15th.

In 2000, conservation tillage was used on 45% of Indiana's cropland. Even though Indiana is a no-till leader among cornbelt states, data suggest that few fields were no-tilled over the long term. Given that most research suggests that no-till benefits to soil begin to appear no earlier than the 3rd consecutive year of no-till, many farmers are abandoning no-till at about the time one would expect its benefits (Evans et al., 2000). Data from the Purdue Agronomy Research Center suggest that over the past 25 years, no-till used in a corn-soybean rotation economically outperformed conventional, mulch, and strip tillage systems (West et al., 1999). Producers should be encouraged to give no-till practices the continuous time necessary to reap yield, economic, and environmental benefits. Hanson Young expects conventional/full tillage to be dramatically increased in 2002 due to rill and gully erosion problems induced by the unusually wet October of 2001.

Producers that switch to a conservation tillage pattern should keep in mind that the normal planting process and management regime may need to be modified or "fine-tuned" for success. Tillage will not longer destroy weeds before planting, and new weed species will invade given the different soil conditions. Treating these new invaders may require different herbicides. Certain crop varieties may not tolerate the change in herbicide regime, so a different crop variety may be required. Yield reduction which at first may be associated with tillage change may be due in fact to a different level of tolerance to a new herbicide (Canada-Ontario Green Plan, 1997).

Nutrient Management

Nutrient Management in the Study Watersheds

Like many agricultural areas, fertilization is an important part of production in the study watersheds. Producers in the watershed area generally apply potash in the fall and anhydrous ammonia during the spring at planting (Hanson Young of the Noble County Purdue Cooperative Extension Agency (PCEA) and Kelly Easterday of the Kosciusko County PCEA). An additional dose of nitrogen is applied to corn crops by many farmers when the crop is knee-high (Jeff Burbrink of the Elkhart County PCEA personal communication). Many producers also grow winter wheat after the corn or soybeans have been harvested so that they can use their manure year-around. Hanson Young estimates that there are six large and 36 smaller dairy operations, two beef operations, "quite a few" sheep raisers, and one duck farm in the Noble County area of the watershed. Due to the frequency of livestock enterprises, manure application is common in the Elkhart and Noble County portions of the watershed (Jeff Burbrink and Hanson Young, personal communication). However, manure application is not common in the area that lies within Kosciusko County (Kelly Easterday, personal communication).

Management of nutrients applied in fertilizer can greatly benefit water quality. The first step in effective nutrient management is regular soil testing. Historically, producers have conducted soil tests only when a problem is noticed. More recently, soil testing once every 3-5 years has become more common among grain producers (Hanson Young, personal communication); however, Jeff Burbrink believes that some local landowners test only once every ten years or not at all. Kelly Easterday also believed that Kosciusko County farmers in the watershed were conducting soil testing once every three years. Many producers, especially those applying manure, have adopted an annual soil testing schedule. Mr. Young noted that those utilizing manure do follow Indiana Department of Environmental Management (IDEM) guidelines for nitrogen and phosphorus application rates.

Fertilizer should be applied based on realistic yield goals; however, most farmers in the area fertilize "on the high side of realistic" resulting in over-fertilization in many years (Hanson Young, personal communication). Jeff Burbrink believes that about 70% of the land is managed for realistic production while about 30% is fertilized based on optimal goals. Producers who also work off-farm are more likely to over fertilize (Jeff Burbrink, personal communication). Producers should also make allowances in nitrogen applications for N contributions of any previous legume crops in the rotation or any legume cover crops. Young stated that most farmers in Noble County use a soy-corn or soy-corn-hay rotation and do account for legume N-addition in their fertilizer regimes. Fertilizer adjustment may also be necessary when transitioning from conventional to conservation tillage.

In special areas of environmental concern, such as fields that border streams and other waterbodies, fertilizer setbacks should be utilized. Setbacks are strips or borders where fertilizer is either not applied or applied in smaller quantities. Fertilizers should not be applied directly next to streams and certainly not in them. According to the Noble County Purdue Cooperative Extension Agency, fertilizer setbacks are accomplished with filter strips, and most farmers are conscientious near tile drains and open ditch areas. Jeff Burbrink feels that farmers are much more aware now of conservation issues than they were 15-20 years ago. Producers on highly erodible land in areas of environmental concern tend to be more conscientious with respect to fertilizer application. Many of the farms continue to be family-operated, and good farming practices are important (Hanson Young, personal communication).

Though not a nutrient in and of itself, *E. coli* bacteria contamination of waterways is an indirect effect of applying animal waste as fertilizer. *E. coli* and other bacteria from the intestinal tracts of warm blooded animals can cause gastroenteritis in humans and pets. Symptoms of gastroenteritis include: nausea, vomiting, stomachache, diarrhea, headache, and fever. Due to high *E. coli* counts, about 81% of the assessed waters in Indiana did not support "full body contact recreation" in 1994-1995 (IDEM, 1995). Of over 800 samples taken in the St. Joseph River in 1996-1997, the average of all samples was 2000 colonies/100 ml, about 16 times the maximum allowable level (Frankenberger, 2001). To prevent manure from entering tiles, ditches, and streams, producers can: 1) apply manure at optimal times for plant uptake; 2) apply when potential for plant uptake is high and runoff is low; 3) inject or incorporate manure to reduce runoff potential; 4) use filter strips; and 5) use setbacks from surface inlets to tile lines.

Nutrient Management Research

Nutrient management has been the focus of agricultural research in many parts of the country. Studies have shown that every year about 15% of the applied, 68 % of the residual in the non-root zone layer, and 20% of the residual nitrogen in the root zone layer are leached to the ground water (Yadav, 1997). To address this concern, the Penn State Cooperative Extension Service designed a nutrient management plan based on: 1) crop yield goals; 2) soil type; 3) methods of manure and commercial fertilizer application; 4) nitrogen concentrations in soils; 5) nitrogen concentrations in manure to be used for fertilizer; 6) crop rotations (Hall and Risser, 1993). With this plan in place: 1) fertilizer application as manure and commercial fertilizer decreased 33% from 22,700 lbs/year to 15,175 lbs/year; 2) nitrogen loads in groundwater decreased 30% from 292 lbs of nitrogen per 1,000,000 gal of groundwater to 203 lbs per 1,000,000 gal; and 3) the load of nitrogen discharged in groundwater was reduced by 11,000 lbs for the site over a three-year period (70 lbs/ac/yr).

Weed and Pest Management

Ground water data assembled by the U.S. Geological Survey (USGS) and the Environmental Protection Agency (EPA) found 18 pesticides and five pesticide breakdown products in 9% of the samples taken in Indiana (Goetz, 2000). Modeling by Purdue University professor Bernie Engel, showed that 75% of detectable pesticides in groundwater came from 25% of farmland. Using his data, Dr. Engel created a pesticide leaching risk map (Figure 13) and helped the State write the Indiana State Pesticide Management Plan that is available on-line at http://www.isco.purdue.edu/psmp/oiscmain.html.

Weed and pest management results in fewer herbicide and pesticide applications at reduced rates and thereby helps to protect the environment by reducing polluted runoff. Proper management of these chemicals entails: 1) being familiar with the threshold at which weed and pest populations begin to cause economic damage; 2) using local weather forecasting to time field scouting to determine if pest problems are great enough to warrant the use of a control measure; 3) planting cover crops to suppress weed growth; 4) planting seed that has been bred for pest resistance during optimal conditions; 5) using insect traps near target crops to track infestations; 6) promoting and attracting natural enemies that help control pests; 7) applying the most effective and appropriate pesticide or herbicide during optimal weather conditions.

Properly functioning tile lines have been shown to reduce pesticide contamination of water by: 1) decreasing runoff so less pesticide is carried in water and 2) when water runs through the soil on its way to tiles, many of the chemicals are adsorbed by soil particles (Goetz, 2000). In fact, compared to pesticide runoff in surface water, relatively little soaks down through the soil into the ground water (Kladivko, 1999). Although it may vary with soil type, the amount of pesticide that enters tile lines is generally less than half a percent of the amount applied. Meanwhile, surface runoff from poorly drained fields during the first or second storm after application can contain 1-2% of the pesticide applied. Based on her research Purdue agronomy professor Eileen Kladivko recommends that farmers properly tile poorly drained fields if they are to be used for production to avoid possible surface water contamination with pesticides (Goetz, 2000).

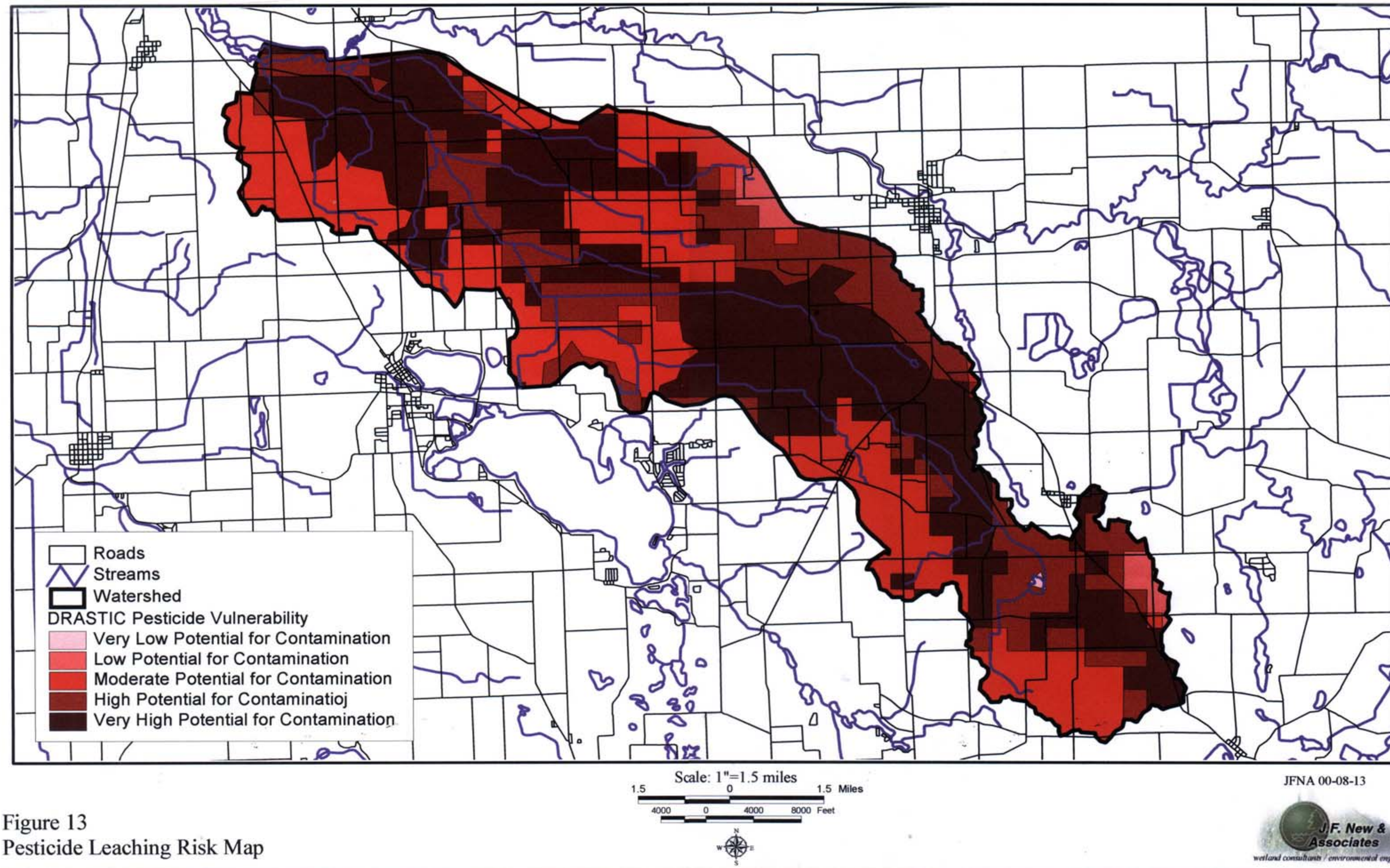


Figure 13
Pesticide Leaching Risk Map

In Noble County, herbicides are applied based on season and weather patterns, while pesticide is applied based on need. Insect scouting is a cooperative effort between farmers and pesticide applicators. In general, farmers scout their fields and notify applicators of potential problems. Pesticide dealers also conduct insect scouting during times of the year when infestations of European corn-borer, bean-leaf beetle, and army worm typically occur. In Elkhart County, pesticide dealers conduct most of the insect scouting according to the Elkhart County Purdue Cooperative Extension Agency. Jeff Burbrink noted that by the time most farmers notice an insect problem, it is usually too late to do anything about it. He thinks that in these cases the farmer would be better off not applying the chemical to save money and possible damage to the environment.

The amount of pesticide applied in the watershed is weather-dependent and varies from year to year but amounts used are never large when compared with other areas. Crop rotation, which is avidly used within the area, helps to break the annual life cycles of most typical crop insects (Jeff Burbrink, personal communication). However, farmers should watch crops closely because a new invader called the root-worm beetle has been found to lay its eggs in soybean fields after the beans have been harvested. The juveniles then hatch the following summer when the corn sprouts. Because many farmers are not accustomed to looking for insects on first year corn, the root-worm beetle is often not noticed until damage has been inflicted.

Resource Management Planning

Resource management planning is an individually based natural resource problem solving and management process advocated by the NRCS (NRCS, 2001). It addresses economic, social, and ecological concerns to meet both public and private needs while emphasizing desired future conditions. NRCS personnel work directly with landowners to understand his or her objectives to ensure that all parties understand relevant resource problems and opportunities and the effects of decisions. The process has three phases and nine steps:

Phase I – Collect and Analyze

1. Identify Problems and Opportunities
2. Determine Objectives
3. Inventory Resources
4. Analyze Resource Data

Phase II – Decision Support

5. Formulate Alternatives
6. Evaluate Alternatives
7. Make Decisions

Phase III – Application and Evaluation

8. Implement the Plan
9. Evaluate the Plan

Though not widely used, Resource Management Plans have met with success in most areas. According to Doug Nusbaum, an agriculture conservation specialist with the Indiana Department of Natural Resources (IDNR), most if not all fields (including highly erodible ones) can be responsibly managed and used for production with the development of a Resource Management Plan. In Elkhart County, Resource Management Planning is the normal planning process (Bev Stevenson, personal communication). Planning involves inventorying the resources, communicating with the landowner about where improvements may be made, and implementing the plan.

Other Conventional Managerial Conservation Practices

The USDA has published specifications for management-oriented practices in addition to the more common ones described above. Again not all practices are applicable in every situation, but managerial BMPs used in concert with structural BMPs are often required to meet conservation goals. A list of the various different conservation practices recognized by the USDA is available online at http://www.ncg.nrcs.gov/nhcp_2.html. Managerial conservation practices that are relevant for use in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds are listed in Appendix 2.

Innovative/Newly Developed Conservation Practices

Introduction

Researchers interested in agriculture and conservation are testing new ideas for production management every day in the U.S. and Canada. A comprehensive literature search was conducted as part of the current study. BMPs that may present promise of benefit in certain situations are presented below. It should be noted that some of the practices have been developed fairly recently, and successful results cannot yet be guaranteed.

Riparian Management System Model

The Agroecology Issue Team of the Leopold Center for Sustainable Agriculture and the Iowa State University Agroforestry Research Team banded together in the early 1990s to promote restoration of the Bear Creek Watershed in central Iowa via development of a riparian management system model. Results of their study provide valuable lessons relative to management decisions and practices in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. The purpose of the study was to design a management system composed of several parts so that each part could be modified individually to meet site conditions and landowner objectives. Specific goals of the management system include: interception of eroding soil and agricultural chemicals, slowing of flood waters, stabilization of streambanks, and provision of wildlife habitat and an alternative, marketable product (Isenhart et al., 1997). The system model consists of a multispecies riparian buffer, streambank stabilization, a constructed wetland, and a rotational grazing strategy (Figure 14).

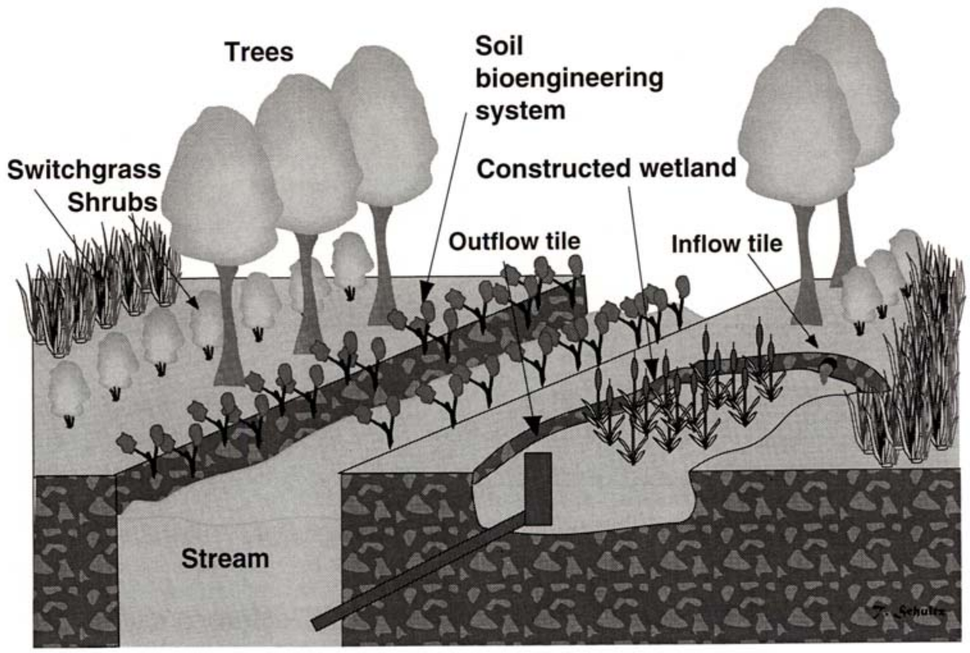


FIGURE 14. The riparian management system model (Isenhart et al., 1997). Used with permission from the American Fisheries Society.

The riparian buffer strip component consists of three zones (Figure 15): 1) A 33-foot-wide strip of trees bordering the stream. Fast-growing, native species like green ash, willow, poplar, and silver maple are recommended. Slower-growing trees like oaks and walnuts may be planted in the outer edge if desired. 2) A 12-foot-wide strip of shrubs. Shrubs, like trees, have permanent rooting structures and offer habitat diversity. Recommended species include ninebark, redosier and gray dogwood, chokeberry, witch hazel, nannyberry, and elderberry. 3) A 21-foot-wide strip of warm-season grasses. Species mixes were discussed in the filter strip section. Altogether the strip is 66 feet wide, but each component may be altered to address landscape requirements, desired buffer physical and/or biological functions, landowner objectives, and cost-share program standards. Appendix 3 includes before and after pictures of a riparian management system installation site in the Bear Creek Watershed.

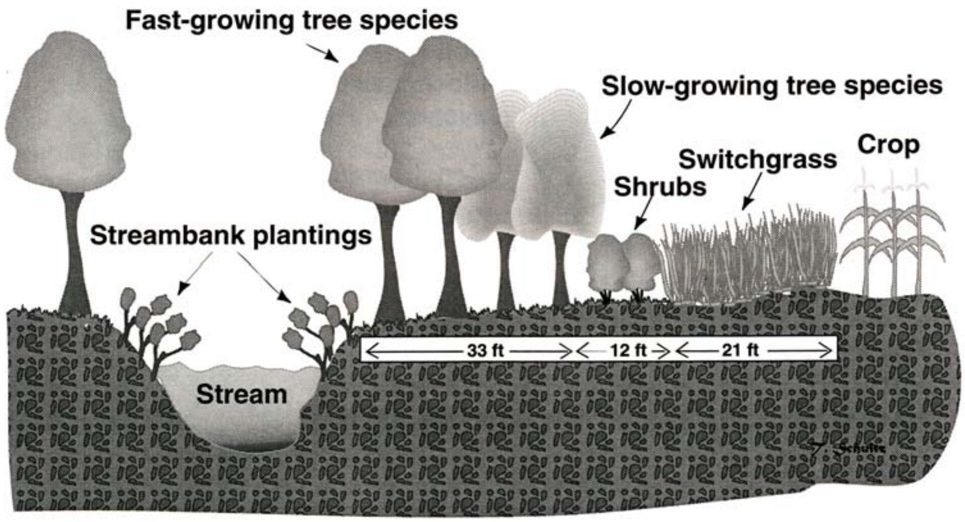


FIGURE 15. The multispecies riparian buffer strip component of the management system model. Used with permission from the American Fisheries Society.

Streambank stabilization using soil and vegetation bioengineering techniques is the second component of the comprehensive riparian management system model. Feasible techniques include installation of native, live plant material in combination with revetments of rock or wood and biodegradable erosion control fabric. According to Klingeman and Bradley (1976) bank vegetation provides a list of stabilization benefits: 1) plant roots hold soils together and in place; 2) above-ground vegetation increases surface flow resistance, decreasing flow velocities and routing energy dissipation toward plant material and away from soils; 3) vegetation buffers the channel from abrasion by materials transported from upstream; 4) vegetation induces sediment deposition, helping to keep soil on the land and to rebuild streambanks.

The final two components of the model include a constructed wetland designed to fit into the 66-foot buffer strip and a rotational grazing system to control livestock stream access. Constructed wetlands have a known track record for nitrate removal (via the process of denitrification) from surface water. In the Iowa study, water from a 12-acre field was tiled into a 2,900 ft^2 (<0.10 acre) wetland. A gated tile at the outlet of the structure provides control of water levels (Figure 14). Vegetation was planted in the wetland to jump-start nutrient uptake (See Appendix 3 for photo and Table 24 for a list of plants recommended for wetland planting). Other studies suggest that a wetland area to cultivated crop area ratio of 1:100 will provide the adequate water retention time during normal runoff events necessary to remove significant nitrate amounts.

TABLE 24. Plant species suitable for filtration and nutrient uptake in restored or created wetlands.

Grasses	Forbs
Redtop	Sweet flag
Creeping bent grass	Common water plantain
Spike rush	Cardinal flower
Common rush	Great blue lobelia
Rice cut grass	Monkey flower
Soft-stem bulrush	Arrow arum
Bur reed	Smartweed
Temporary Grasses	Pickerel weed
Seed oats	Broad-leaf arrowhead
Annual rye	

*** Seed the permanent grasses at 3 lbs/acre, the temporary grasses at 42 lbs/acre, and the forbs at 2.75 lbs/acre.**

An important part of any study, the Bear Creek project sites were monitored for success (Isenhart, et al., 1997). The monitoring studies indicated that the 21-foot-wide switchgrass component of the model reduced sediment load to the stream by 75%. Nitrate-nitrogen concentrations moving in groundwater below the buffer were markedly lower than those moving below the adjacent, cropped field. Nitrate levels below the buffer never exceeded 2 mg/l while levels below adjacent fields consistently exceeded 12 mg/l (Schultz et al., 1995). In contrast, groundwater nitrate concentrations in a field cultivated to the stream's edge showed no reduction nearer the stream. Wildlife use of the restored area was also markedly improved. While only four bird species per day were observed in channelized reaches, 18 species per day were recorded in 4-year-old buffer sections. Additionally, constructed wetland outflow concentrations of nitrate-nitrogen were significantly lower than inflow concentrations during most sampling periods.

The Iowa management system model provides valuable lessons for management within the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. The approach is flexible for site-specific conditions and respectful of private landowners' desires and objectives. Within the Bear Creek Watershed, two relatively small sites were initially built and then used to garner the interest and support of other landowners. Similar management system models hold great promise for application within the study watersheds and include the following major advantages: 1) interception of eroding soil; 2) trapping and transformation of non-point source pollution; 3) stabilization of stream banks; 4) provision of wildlife habitat; 5) production of biomass for on-farm use; 6) production of high-quality hardwood; and 7) enhancement of agro-ecosystem aesthetics (Schultz et al., 1995).

Natural Nitrification Stimulation

Growers Nutritional Solutions of Milan, Ohio has researched and recommends a nutrient management plan that stimulates natural nitrification processes in the soil. The program has been recognized by the Environmental Protection Agency (EPA) as having environmental benefits because less commercial nitrogen needs to be applied (Halbeisen, 2001). The plan has applications and can be used in both agricultural and residential lawn care situations.

The natural nitrification program involves: 1) supplying adequate amounts of calcium to the soil profile and 2) foliar fertilization using high-grade, balanced fertilizer solutions. Research shows that calcium: 1) stimulates nitrogen-fixing soil bacteria like *Azotobacter* which can fix 15-40 lbs of nitrogen/acre/year (Smith et al., 1953); 2) prevents increased solubility of iron and aluminum which negatively affect nitrogen fixation; 3) increases soil porosity and oxygen exchange which is important for conversion of nitrogen to a form that can be used by plants; 4) stimulates earthworm populations, which shred organic matter for bacterial consumption and help to decrease soil compaction. The second part of the program requires applying a small amount of balanced fertilizer on the seed at planting. The crops are then fed through the foliage at certain stages of development. Research shows that foliar-applied fertilizer is used more efficiently than soil-applied nutrition (Joint Committee on Atomic Energy, 1954). Advantages of using the two part program include: 1) lowered use of applied nitrogen; 2) sound economic productivity; 3) higher grain weights; 4) better produce flavor and shelf life; 5) fewer livestock veterinary visits (Halbeisen, 2001).

Integration of Nitrogen and Phosphorus Management

Recent research has suggested the need for integrated nitrogen and phosphorus management to account for spatial variation in nutrient loss risk (Heathwaite et al., 2000). While nitrate-nitrogen loss is a threat to ground water supplies, phosphorus loss threatens rivers, lakes, and oceans with eutrophication (overproduction). Nitrogen as nitrate is highly mobile in leaching water and is primarily lost through subsurface runoff. (Figure 16 shows areas of the state that are vulnerable to nitrate loss via leaching according to modeling work by Purdue University engineering professor Bernie Engel.) On the other hand, phosphorus is predominantly lost via surface runoff. Because the two nutrients are transported by such different mechanisms, different management tools should be employed depending on which nutrient is of the highest risk of being lost. For example, it does not make sense to prioritize management of phosphorus in an area of the watershed that rarely contributes surface runoff and that does not receive high amounts of the nutrient. Different sections of even a single tract of land may need to be managed differently based on risk of nutrient loss.

In many cases, “across-the board” management of only one nutrient may in fact heighten the risk of pollution by the other. For example, when manure fertilization regimes are based on soil nitrogen content alone to manage nitrate leaching, phosphorus is often over-applied. The amount of phosphorus applied relative to nitrogen (N:P = 2:1 to 6:1) is often greater than that which can be taken up by crops (N:P = 7:1 to 11:1) (Eck and Stewart, 1995). In contrast, use of artificial drainage to reduce phosphorus loss by reducing surface runoff may enhance nitrate leaching through the ground (Turtola and Paajanen, 1995).

Individual tracts of land can be assessed for nutrient loss risk by applying nitrogen and phosphorus indexing systems to assign risk ratings (Heathwaite et al., 2000). The nitrogen index is based on soils texture and permeability, fertilization rate and method, and manure application rate and method. The phosphorus index is based on erosion potential, amount of runoff that leaves the site, distance from the site to the nearest waterway, soil test phosphorus, fertilization rate and method, and manure application rate and method. By calculating the index value for each nutrient, loss vulnerability for the site can be determined and management tailored accordingly.

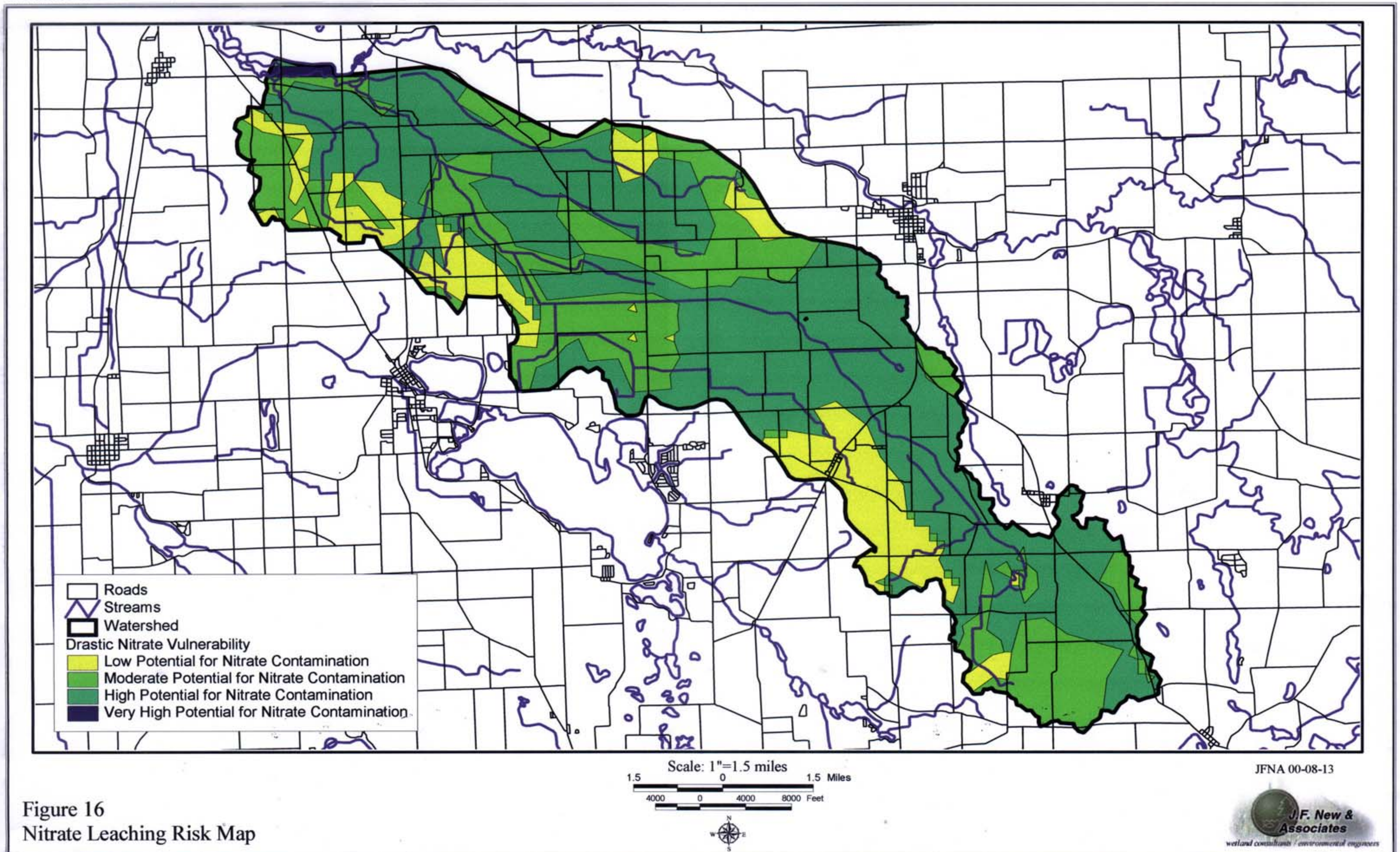


Figure 16
Nitrate Leaching Risk Map

In areas that are phosphorus-loss prone, fertilizer and manure applications should be appropriately modified and features that slow surface runoff should be installed (i.e., constructed wetlands and filter strips). In areas where nitrogen loss is a hazard, nitrogen sources and sinks like fertilizer, crop type, and crop rotation should be carefully monitored. Different management priorities may be suited to different areas of a watershed or tract of land.

Water Treatment Residual Application to Reduce Nutrient Loss

Recent research shows that residual chemicals produced during the drinking water purification process may retard nutrient loss from animal wastes applied as fertilizers (Gallimore et al., 1999). Water treatment residuals (WTR) are composed of sediment, aluminum oxide, activated carbon, and polymer. Runoff from plots fertilized with poultry litter including WTRs contained 50% less dissolved phosphorus and 66% less ammonium when compared to runoff from control plots which received poultry litter alone. Land application of the WTR did not increase total dissolved solids or aluminum in surface runoff. The study did note, however, that WTR may damage pasture vegetation and is discouraged (Gallimore et al., 1999).

Nitrification Inhibitors

Nitrification inhibitors are chemicals that can be applied that retard the nitrification process that results in the conversion of ammonium to nitrate. Inhibitor use is especially relevant when there is a gap between applying nitrogen and planting crops. Nitrate reductions of 8 mg/l in the groundwater and nitrate leaching rate reductions of 44.8 kg/ha/yr have been documented in the literature (Yadav, 1997).

Systems of BMPs

Although individual BMPs are commonly and have traditionally been used, recent work shows that BMPs used in concert working as a system will often be more effective at pollution control than individual practices (Osmond et al., 1995). Systems of BMPs function to minimize the pollutant at several points including the source, the transport process, and the water body. For example, the goal of an Iowa Rural Clean Water Program (RCWP) project, was to protect Prairie Rose Lake which was receiving sediment from the surrounding watershed. The BMPs critical area planting and conservation tillage were used to diminish soil loss from agricultural land, while terraces, underground outlets, diversions, grassed waterways, and detention basins were constructed to slow sediment transport to the lake (Osmond et al., 1995).

BMP Summary

Agricultural BMPs are currently used in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. While most subwatershed basins within study area contain little HEL, the Solomon Creek East, Whetten Ditch, and Meyer/Cromwell Ditch Subwatersheds do contain significant acreages of unprotected highly erodible land. Due to relative lack of current CRP participation, these areas should be targeted in future sign-up efforts and prioritized for BMP installation. Although some cropland within the watersheds is treated using filter strips and grassed waterways, more participation should be sought and encouraged, particularly on highly erodible tracts that border waterways. Currently, some non-protected HEL tracts directly border Solomon Creek and its tributaries. Conservation tillage is readily used throughout the study watersheds, but farmers should be encouraged to stay with the minimum till practices longer than 2-3 years. The best way to protect against soil loss is to keep the soil covered, minimizing disturbance. As a result of conservation tillage used in combination with other BMPs, 75% of Indiana's cropland is losing soil at or below the tolerable level of T for the 2000 growing season (Evans et al., 2000). In fact, scientific evidence indicates that about 80% of environmental issues that result from cropland can be corrected by integrating BMPs into farm management (CTIC, 1999). Comprehensive land management through development of individual Resource Management Plans is highly recommended.

Stream Chemistry Studies

Introduction

Stream chemistry studies have been conducted in the study area by the Elkhart County Health Department (ECHD), the Indiana Department of Environmental Management (IDEM), the Water Quality Monitoring Joint Coordination Project led by John Rouch, and by Lawson-Fisher. The ECHD tested for *E. coli* and nitrate at one site in the Solomon Creek Watershed during the years of 1995 through 1998 (Figure 17). IDEM assessed water chemistry in Solomon Creek at one site (Figure 17) in the late summer and fall of 2000 as part of the Lower Elkhart River Assessment. Solomon Creek was also sampled on various dates throughout 1999 and 2000 at two locations (Figure 17) by participating members of the Water Quality Joint Coordination Project, a partnership between the St. Joseph River Basin Commission and the St. Joseph, Elkhart, LaGrange, Noble, Steuben, and Kosciusko County Soil and Water Conservation Districts (SWCDs). Lawson-Fisher most recently sampled various stream chemistry parameters as part of a 319 Program Grant in Whetten Ditch and Dry Run (Figure 17). Because the earliest data was collected in 1995, historical trend analysis was not possible. (Please see the Water Chemistry Methods Section for a more detailed description of water quality parameters.)

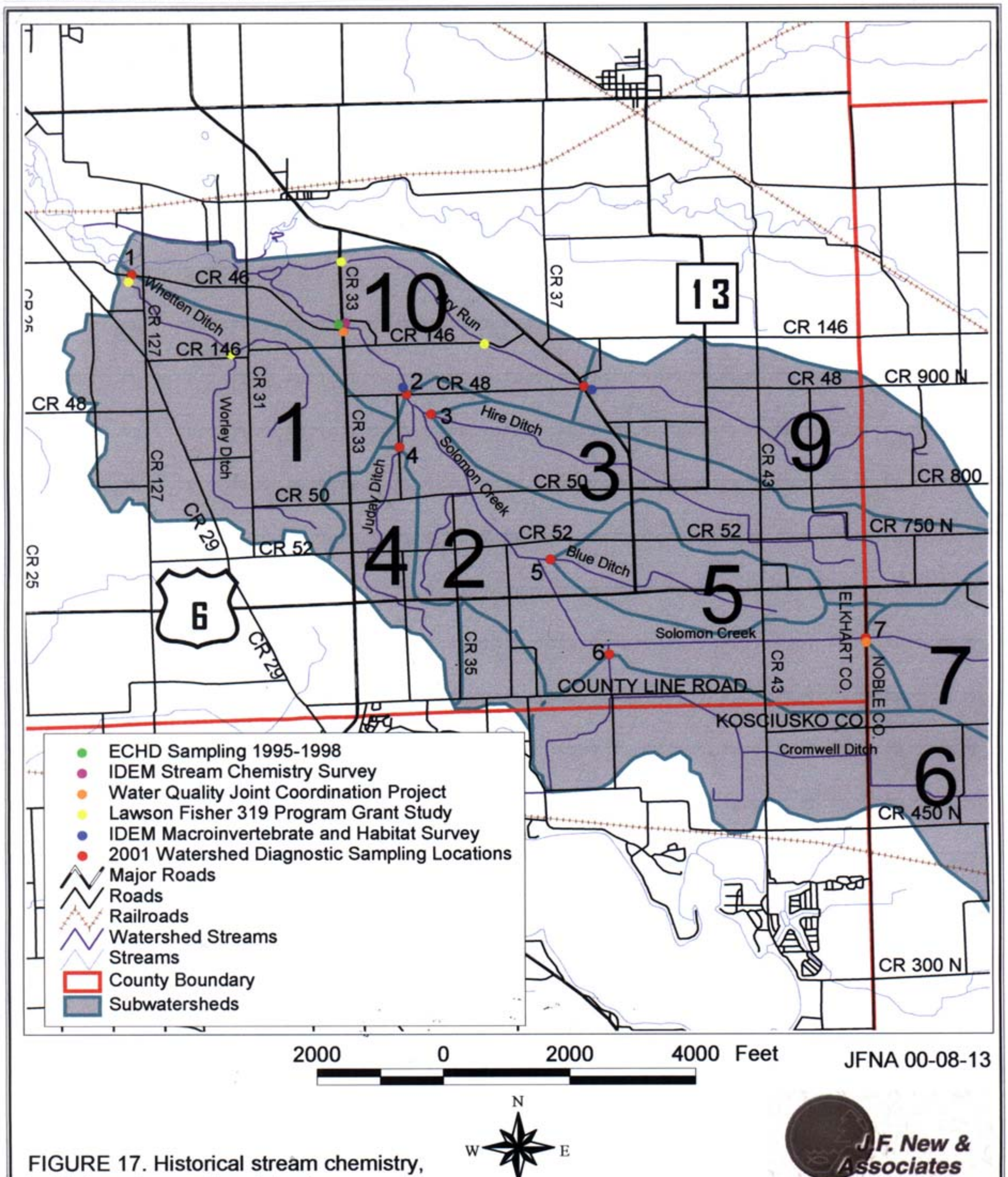


FIGURE 17. Historical stream chemistry, habitat, and macroinvertebrate community survey locations.

ECHD Study

The ECHD sampled Solomon Creek at its intersection with CR33 in 1995-1998. Although sampled a bit further upstream, this data is comparable with data collected during this study at Site 2. According to Table 25, *E. coli* concentrations ranged from 240-6000 col/100 ml. Measured concentrations exceeded the acceptable Indiana state standard of 235 col/100 ml in every sample collected (Figure 18). The highest nitrate measurement taken was 21 mg/l though most nitrate concentration data fell below the 10 mg/l standard for drinking. (Again, standards and parameters will be discussed in more detail in the Water Chemistry Methods Section.)

TABLE 25. Solomon Creek *E. coli* and nitrate concentration data collected at one site by ECHD during the years of 1995-1998.

Date	Nitrate (mg/l)	*E. coli* (col/100 ml)
5/18/95	2.3	430
5/25/95	7.06	2450
6/1/95	21	375
6/8/95	2.81	410
6/22/95	2.35	380
6/29/95	11.1	730
7/6/95	2.32	485
7/13/95	1.78	255
7/20/95	2.09	340
7/27/95	0.97	605
8/10/95	2.14	560
8/17/95	NS	270
6/6/96	2.88	555
7/11/96	1.6	270
7/18/96	1.42	3200
7/25/96	1.03	260
8/1/96	1.38	350
8/8/96	3.1	410
8/15/96	1.44	555
8/22/96	1.38	750
8/29/96	3.96	310
9/5/96	7.24	405
9/12/96	3.75	240
9/19/96	3.52	245
9/26/96	3.87	360
5/29/97	4.08	503
6/12/97	0.12	4300
6/19/97	6.4	255
6/26/97	5.73	6000
7/3/97	5.3	590
7/24/97	3.7	280
7/17/97	6.63	410
7/31/97	3.26	255

8/7/97	6.5	255
8/14/97	1.93	393
8/21/97	2.84	355
9/18/97	1.57	1350
5/21/98	1.1	255
5/28/98	0.70	240
6/4/98	2	335
6/18/98	2.6	463
7/2/98	0.7	518
7/16/98	1.2	370
7/31/98	1.1	315
8/13/98	2.21	468
8/27/98	1.91	390
9/10/98	0.32	700

NS = Not sampled.

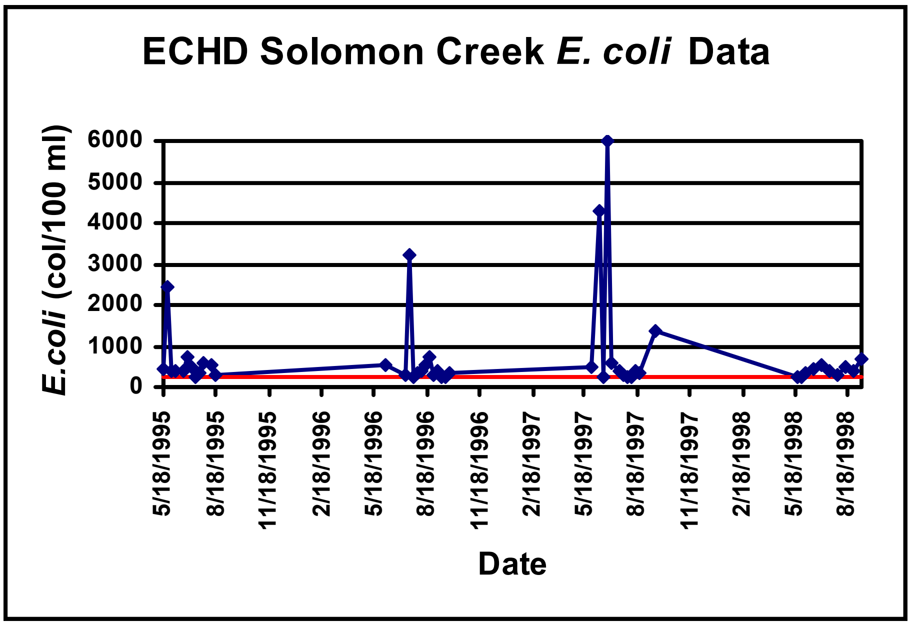


FIGURE 18. *E. coli* data as sampled by the ECHD in 1995-1998. The red line indicates the Indiana state standard of 235 col/100 ml for any one sample collected during a thirty day period.

IDEM Study

The site on Solomon Creek sampled by IDEM for stream chemistry in 2000 is close in proximity to Site 2 sampled during the current study. Table 26 presents the data gathered by IDEM during the five sampling episodes. All samples fell within acceptable standard limits except for the *E. coli* measurement taken on 10/18/2000. This sample exceeded Indiana state standards by 565 CFU/100 ml (CFU=Colony Forming Unit).

TABLE 26. Solomon Creek stream chemistry data collected at one site by IDEM during five sampling episodes in 2000.

Date	DO (mg/l)	pH	Temp. (°C)	Conductivity (µmhos)	Turbidity (NTU)	*E. coli* (CFU/100ml)
9/29/2000	11.29	8.08	9.66	829	10.2	230
10/3/2000	11.65	8.05	13.98	756	5.9	80
10/11/2000	8.34	8.09	9.2	1519	11.2	100
10/18/2000	10.36	8.07	10.73	1423	6.5	820
10/25/2000	8.98	7.88	14.83	1454	5.3	30, 50*

Data was provided by Chuck Bell with the IDEM Data Group.
DO = Dissolved Oxygen
* Replicate *E. coli* samples were taken on 10/25/2000.

Water Quality Monitoring Joint Coordination Project Study

The Water Quality Monitoring Joint Coordination Project was completed under the auspices of an EPA §319 Grant in the fall of 2000. The project was conducted within five counties that contribute water to the St. Joseph River and was a partnership among the St. Joseph River Basin Commission and the St. Joseph, Elkhart, LaGrange, Noble, Steuben, and Kosciusko County SWCDs. John Rouch and several volunteers and volunteer groups in the area collected and analyzed the monitoring data.

The two sites sampled by the Water Quality Monitoring Joint Coordination Project are also comparable to Sites 2 and 7 sampled during this study. Participating volunteer groups measured nine different water quality parameters as described by Mitchell and Stapp (Rouch, 2000). The nine tests are those considered to be most relevant for determining stream water quality according to the National Sanitation Foundation (Rouch, 2000). Data for each parameter was assigned a quality value, and a Water Quality Index (WQI) for the site was then calculated by summing the individual parameter values. Table 27 contains data from the study.

TABLE 27. Solomon Creek stream chemistry data and WQI values gathered at two sites by the Water Quality Monitoring Joint Coordination Project. A WQI score of 90-100% indicates excellent, 70-90% good, 50-70% medium, 25-50% bad, and 0-25% very bad stream quality (Rouch, 2000).

Site	Date	DO	%Sat	*E.coli*	pH	BOD	Temp Δ	TP	NO_3^-	Turb.	TSS	NH_3	WQI
CR146	10/13/99	9.82	94.5	290	7.9	0	0.1	0	2.64	6.24	457	0	79
CR146	4/11/00	11.6	94.3	340	7.7	0	0.0	0	5.28	8.61	488	0	77
CR146	8/10/00	9	90	942	7.5	8	0.0	0	0	20	139	0	74
CR146	8/30/00	9.6	100.5	440	7.9	0	-0.6	0	2.64	4.76	492	0	78
CR146	10/10/00	11.9	98.3	130	7.9	0	0.0	0	3.96	7.8	514	0	76
CR1200W	10/6/99	9.58	84.3	70	7.5	0	0.3	0.12	3.08	11.3	450	0	80
CR1200W	4/11/00	11.3	84.4	280	7.5	0	-0.7	0.15	5.28	9.42	497	0	75
CR1200W	7/25/00	3	33	0	8.3	2		0.57	1.23	3.5	487	0	67
CR1200W	8/30/00	11.5	126	580	7.8	0	3.3	0.22	26.4	12.1	511	0	66
CR1200W	10/10/00	12.8	108	91	7.8	0	-0.2	0.12	3.52	8.1	497	0	77

Data was taken from Rouch, 2000.
DO=Dissolved Oxygen in mg/l
%Sat=percent oxygen saturation in water sample
E. coli is measured in colonies/100 ml.
BOD=Biochemical Oxygen Demand in mg/l
Temp Δ=Change in temperature over a given stream length
WQI=Water Quality Index
TP=Total Phosphorus in mg/l
NO_3^-=Nitrate in mg/l
Turb.=Turbidity in Nephelometric Turbidity Units (NTUs)
TSS=Total Suspended Solids in mg/l
NH_3=Unionized Ammonia in mg/l

The Water Quality Monitoring Joint Coordination Project WQI calculations places water quality in Solomon Creek consistently in the medium to good range. Aside from two dates when percent oxygen saturation sagged and BOD was detectable, oxygen concentrations were suitable Only two of the ten *E. coli* samples exceeded the Indiana state standard of 235 CFU/100 ml. Temperature was mostly stable in the creek, but total phosphorus estimates exceeded concentrations known to induce eutrophication in receiving waterbodies. While ammonia concentrations were never detectible, nitrate concentrations were below 10 mg/l (the level at which nitrate becomes dangerous in drinking water) except at the CR 1200W site on August 30. Total suspended solid concentrations were elevated at every site on every sampling date.

Lawson-Fisher 319 Program Project

Lawson-Fisher recently sampled Whetten Ditch and Dry Run as part of a 319 Program grant which was targeted at quantifying the need for an Elkhart Countywide sewer system. The 319 downstream site on Whetten Ditch corresponds with Site 1 sampled during this study (Figure 17). According to the report, data was collected during base flow conditions. Both of the 319 locations on Dry Run are downstream of the site sampled during this study. In general, nitrate concentrations were elevated, and dissolved oxygen concentrations and percent saturation were lower than optimal (Table 28). The prioritization of watersheds based on sewer system need in Elkhart County placed Whetten Ditch and Dry Run as 5th and 6th respectively. The 319 grant ranking was based on *E. coli* data collected from 1995-2001. This watershed ranking and prioritization was based on maximum concentrations of *E. coli* experienced during one sampling event during 1995-2001. Watersheds with more than one site exceeding water quality standards were generally prioritized higher than sites with only one site exceeding. According to the report, *E. coli* concentrations measured in the Solomon Creek-Meyer Watershed and the Solomon Creek-Hire Ditch Watershed were not elevated enough to result in prioritization of these areas.

TABLE 28. Dry Run and Whetten Ditch stream chemistry data collected by Lawson-Fisher at four locations during the 319 Program Project in Elkhart County. Samples were collected on 11/7/01.

Watershed	Location	Temp. (°C)	pH	Cond.	TDS	Color	DO (mg/l)	DO (% sat)	Nitrate (mg/l)	TKN (mg/l)
Elkhart River-Whetten Ditch	CR 146	10.0	7.6	303	151	Turbid	4.3	39.2	7.4	0.59
Elkhart River-Whetten Ditch	CR 46	10.8	7.82	322	160	Clear/Tint Yellow	7.4	66.2	2.6	1.2
Elkhart River-Dry Run	CR 146	10.2	7.81	373	183	Turbid	7.5	64.6	7.6	0.22
Elkhart River-Dry Run	CR 33	9.7	7.73	374	186	Clear	5.4	46.4	6.4	<0.1

IDEM 303(d) List

Once every two years, IDEM publishes the 303(b) report which reports on the status of water quality in the State of Indiana. The 303(b) report includes the 303(d) list which names the "impaired waterbodies" that will be targeted for Total Maximum Daily Load (TMDL) development in the future. Although neither Whetten Ditch, Solomon Creek, nor Dry Run are currently on the list, *E. coli*, mercury, and polychlorinated biphenyls (PCBs) currently impair water quality in the Elkhart River which does appear on the 303(d) list (Figure 19). Because a river's major source of *E. coli* is often its watershed and because some samples have shown elevated concentrations of the bacteria, this parameter is certainly of concern in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

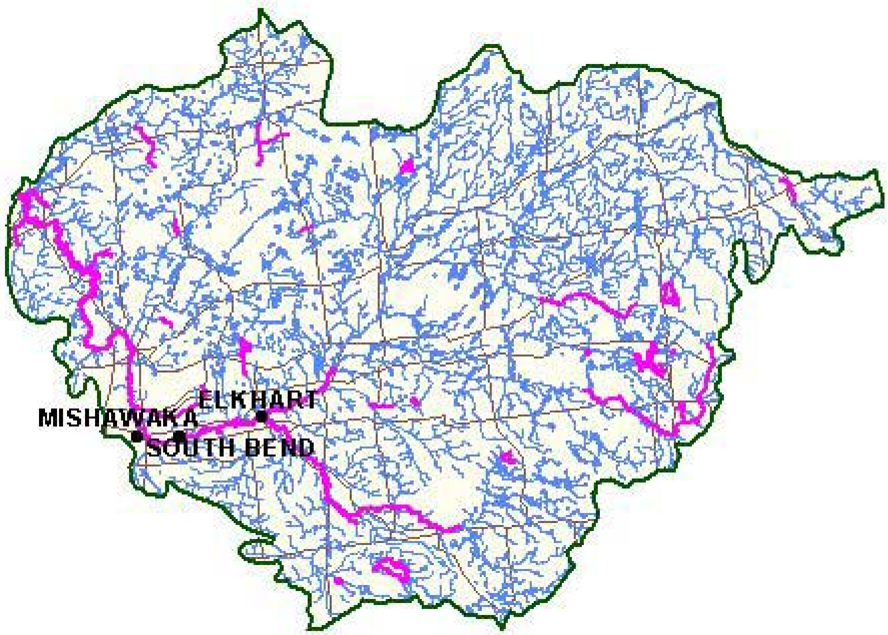


FIGURE 19. 303(d) listed waterbodies in the St. Joseph River Basin.

Macroinvertebrate Community and Habitat Studies

Introduction

IDEM and the Water Quality Monitoring Joint Coordination Project also assessed water quality within the study watershed using macroinvertebrate analyses. The IDEM study included collection of habitat data as well for one site on Dry Run and one on Solomon Creek in 1990 (Figure 17). The Water Quality Monitoring Joint Coordination Project collected macroinvertebrates at the same two locations described above in the Stream Chemistry Studies Section (Figure 17).

IDEM Study

The IDEM Biological Studies Section recorded habitat characteristics and sampled macroinvertebrates in Dry Run on 9/8/90 and in Solomon Creek on 9/27/90. The site on Dry Run closely corresponds to Site 9 sampled during this study, while the site on Solomon Creek is between Sites 2 and 3 of the current study. IDEM's results will be compared with results from this study in the Stream Sampling and Assessment Section. Results of the habitat analysis and macroinvertebrate counts are given in Tables 29 and 30.

TABLE 29. Qualitative Habitat Evaluation Index (QHEI) scores for sites on Dry Run and Solomon Creek as assessed by the IDEM Biological Studies Section on August 8 and 27, 1990.

Site	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	Total
Maximum Possible Score	20	20	20	10	12	8	10	100
Dry Run	15	6	8	8	5	3	6	51
Solomon Creek	14	12	12	8	0	4	6	56

TABLE 30. mIBI (macroinvertebrate index of biotic integrity) scores for Dry Run and Solomon Creek sampled by the IDEM Biological Studies Section on August 8 and 27, 1990.

	Value	**Metric Score**
Dry Run		
HBI	4.43	6
No. Taxa (families)	216	6
No. Individuals	8	2
% Dominant Taxa	40.7	4
EPT Index	129	6
EPT Count	3	2
EPT Count/Total Count	40	4
EPT Abun./Chir. Abun	3.22	4
Chironomid Count	0.60	6
No. Individuals/Square	216	6
mIBI Score		**4.6**
Solomon Creek		
HBI	5.17	2
No. Taxa (families)	116	2
No. Individuals	16	6
% Dominant Taxa	33.6	4
EPT Index	15	0
EPT Count	5	4
EPT Count/Total Count	39	4
EPT Abun./Chir. Abun	0.38	0
Chironomid Count	0.13	0
No. Individuals/Square	29	0
mIBI Score		**2.2**

In general, habitat quality was not found to be conducive to aquatic life, scoring 51 and 56 of a possible 100 points for Dry Run and Solomon Creek respectively. While mIBI scores indicate only slight water quality impairment in Dry Run, the considerably lower score of 2.2 of a possible 8 points at the Solomon Creek site indicate severe to moderate degradation (IDEM, 1996). Both the QHEI and the mIBI will be discussed in more detail in the Stream Sampling and Assessment Section.

Water Quality Monitoring Joint Coordination Project Study

Five macroinvertebrate samples were collected by the Water Quality Monitoring Joint Coordination Project Study in 1999 and 2000 from two sites on Solomon Creek (Rouch, 2000). Pollution tolerance points were assigned to each individual collected based on broad pollution tolerance classes. For example, each stonefly, mayfly, caddis fly, Dobsonfly, and riffle beetle received four points since these organisms are generally pollution intolerant. On the other hand, aquatic worms, blood midges, and rat maggots tolerant poor conditions and receive only one point per individual collected. All points were then summed to estimate the Pollution Tolerance Index (PTI) value (Table 31). The average PTI scores for Solomon Creek indicates good water quality at both sites that were sampled although individual samples taken suggest a seasonal fluctuation.

TABLE 31. PTI scores calculated by the Water Quality Monitoring Joint Coordination Project at two sites on Solomon Creek.

Location	Date	PTI Score
Solomon Creek at CR 46	9/27/99	23
Solomon Creek at CR 46	8/10/00	10
Solomon Creek at CR 46	10/10/00	32
Solomon Creek at CR 1200W	10/11/99	17
Solomon Creek at CR 1200W	10/13/00	26

PTI Scale: >23=excellent; 17-22=good; 11-16=fair; <10=poor

Fish Community Studies

Introduction

The Indiana Department of Natural Resources (IDNR) and IDEM have conducted several fisheries and fish community surveys in the study watersheds over the past 30 years (Figure 20). Solomon Creek was surveyed in 1971,1973, and 1990 by the IDNR Division of Fish and Wildlife and in 1991 by IDEM Biological Studies Section. IDEM also assessed the fish community at one site on Dry Run in 1991. IDNR surveys are generally targeted at evaluation of the existing sport fishery and any other attributes that may affect the fishery. IDEM surveys are intended to assess water quality by evaluating the quality of the organisms living in the water.

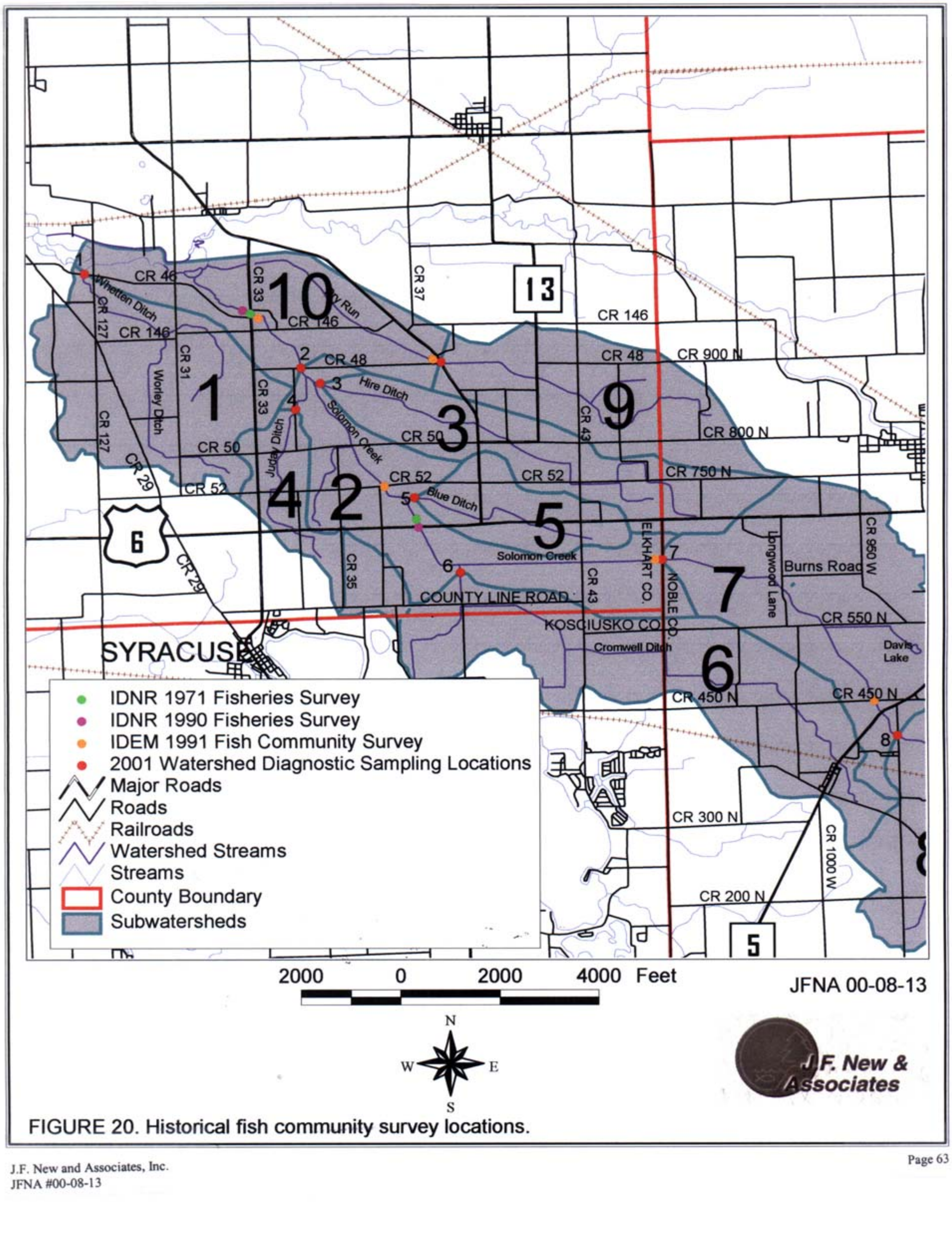


FIGURE 20. Historical fish community survey locations.

IDNR Studies

In July of 1971, Solomon Creek was sampled at two sites as part of the Elkhart River Basin Stream Survey Report (Figure 20; Peterson, 1971). Collection of fish in Solomon Creek just north of SR 6 resulted in 16 species representing seven families (Table 32). Creek chubs, common shiners, white suckers, and Johnny darters accounted for nearly 90% of the community. Peterson (1971) reported that a private landowner had removed large quantities of gravel from the streambed and that the gravel streambed was silted over from farmland runoff.

TABLE 32. List of fish species sampled from Solomon Creek in 1971 and 1990. An X indicates the presence of that species for that year's survey.

Common Name	Scientific Name	1971	1990
Blacknose dace	*Rhinichthys atratulus*	X1,2	X3,2
Bluntnose minnow	*Pimephales notatus*	X1,2	X3,2
Common carp	*Cyprinus carpio*	X1	X3,2
Central mudminnow	*Umbra limi*	X1	X3,2
Central Stoneroller	*Campostoma anomalum*	X1,2	X3,2
Common shiner	*Luxilius cornutus*	X1	X2
Creek chub	*Semotilus atromaculatus*	X1,2	X3,2
Grass pickerel	*Esox americanus*	X1,2	X3
Johnny darter	*Etheostoma nigrum*	X1,2	X3,2
Northern hog sucker	*Hypentelium nigricans*	X1,2	X3,2
Northern pike	*Esox lucius*	X1	
Pirate perch	*Aphredoderus sayanus*	X1	
Pumpkinseed sunfish	*Lepomis gibbosus*	X1	
Rainbow darter	*Etheostoma caeruleum*	X1	
Rainbow trout	*Oncorhynchus mykiss*	X2	
Suckermouth minnow	*Phenacobius mirabilis*	X2	
White Sucker	*Catostomus commersoni*	X1,2	X3,2
Yellow perch	*Perca flavescens*	X1	
Orangethroat darter	*Etheostoma exile*		X3,2
Brown trout	*Salmo trutta*		X3
Blackside darter	*Percina maculata*		X3,2
Fathead minnow	*Pimephales promelas*		X3,2
Golden redhorse	*Moxostoma erythrurum*		X3,2
Green sunfish	*Lepomis cyanellus*		X2
Rock Bass	*Ambloplites rupestris*		X2
Hornyhead chub	*Nocomis biguttatus*		X2
Largemouth bass	*Micropterus salmoides*		X2

Source: Peterson, 1973 and Ledet, 1991
1= Site near SR 6
2= Site near SR 13
3= Site near CR 52

Twelve species of fish representing five families were collected during the second 1971 survey of Solomon Creek near SR 13. While creek chubs, johnny darters, and blacknose dace accounted for the majority of the fish collected, one rainbow trout was collected. This fish was the results of IDNR fish stocking at the SR 13 bridge that crosses the creek. Due to good water quality and general stream conditions, Peterson (1971) recommended the continuation of yearly trout stocking.

The IDNR surveyed fish and wildlife resources in the Elkhart River Basin in the summer of 1972 (IDNR, 1973). Solomon Creek, Dry run, and Cromwell Ditch were assessed during the survey. Solomon Creek was found to support panfish and sucker angling but was described as a former trout stream which “is now possibly too sluggish for trout survival” (IDNR, 1973). Dry Run and Cromwell Ditch were deemed to carry insufficient water to be of significance for sport fish and wildlife.

In 1990, another IDNR fisheries survey was conducted at two locations on Solomon Creek (Figure 20; Ledet, 1991). The general goal of the study was to evaluate trout stocking program success, water quality, and fish habitat. Ledet (1991) noted that the creek is annually stocked by the IDNR with rainbow trout from SR 13 upstream to CR 50 and by the Elkhart Conservation Club with brown trout. Fifteen species were collected at the first site just upstream from CR 52 (Table 32). Blacknose dace, white sucker, and creek chub accounted for 84% of the sample, and only one brown trout was caught. Habitat was considered to be satisfactory in the reach offering a shrub/hardwood riparian zone, abundant pool-riffle complexes, undercut banks, and in-stream vegetation.

The second 1990 survey conducted near SR 13 resulted in a total of 18 species. Blacknose dace, creek chub, and white sucker again dominated the catch; however, no trout were collected from the site. Ledet (1991) noted that sand/gravel substrate, sunken logs, and deep pools provided adequate habitat for trout and other species within the reach.

Based on 1971 and 1990 IDNR data, Figure 21 compares changes in percent composition of the three dominant families: the perch family (Percidae), the sucker family (Catostomidae), and the minnow family (Cyprinidae). The perch and sucker families have experienced significant changes in relative abundance while the relative percentage of minnow family members was decreased by a decrease in darter numbers between 1971 and 1990. In general, darters are sensitive to environmental degradation, requiring sand and gravel free of excessive silt build-up in moderate to swiftly moving, highly oxygenated waters. Silt deposition and channelization noted by Peterson (1971) could have resulted in destruction of darter habitat. In contrast to perch family numbers, a greater percentage of suckers were collected in 1990 when compared to 1971. This difference is the result of an increased population of white sucker, a species tolerant of silt and habitat degradation. The increase in population of this highly tolerant species may indicate habitat and/or water quality degradation in these reaches of Solomon Creek.

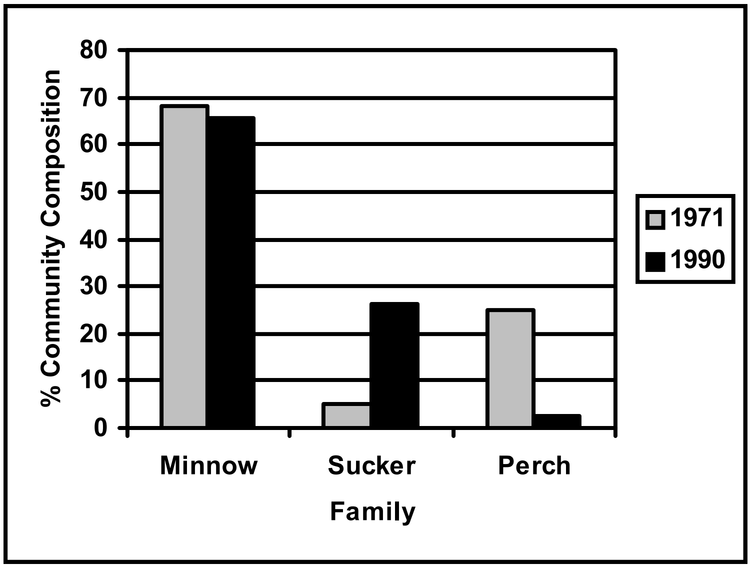


FIGURE 21. Percent community composition of the three most abundant families sampled from Solomon Creek during the 1971 and 1990 IDNR fisheries surveys. Data was taken from Peterson (1971) and Ledet (1991).

IDEM Study

As part of their assessment of water quality in Indiana, IDEM uses fish communities as an indicator of stream biological integrity or health. Biological integrity has been defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to the best natural habitats within a region" (Karr and Dudley, 1981), and biological communities reflect watershed conditions since they are sensitive to changes in a wide array of environmental factors (Karr, 1981). To provide a method of determining biological integrity, Karr (1981) developed the Index of Biotic Integrity (IBI). Simon (1997) further modified the IBI for evaluation of warmwater stream communities located in the Northern Indiana Till Plain Ecoregion of Indiana. The IBI is composed of 12 metrics which are each individually scored based on types and numbers of fish collected in each sample. A score of 12-22 would indicate very poor stream quality while the maximum score of 60 would indicate excellent conditions.

IDEM conducted five fish community surveys within the Solomon Creek and Dry Run Watersheds (Figure 20) and calculated the IBI scores for each site in 1991 (Table 33). IBI values ranged from a high of 40 (fair) at the intersection of Solomon Creek with CR 146 and with County Line Road to a low of 33 (poor) at the intersection of Dry Run with SR 33. IBI scores at Solomon Creek's intersection with SR 13/6 and CR 450 both scored between 34-40 (fair to poor). No site received a good (48-52) or excellent (58-60) score. In most cases the IBI score suffered due to low numbers of sensitive species and high numbers of pollution tolerant species. The percentage of fish species that consume insects was also low in all samples, indicating that conditions were not conducive for growth of a healthy macroinvertebrate community either.

TABLE 33. IBI and integrity class for sites in the Dry Run and Solomon Creek Watersheds as sampled by the IDEM Biological Studies Section in the summer of 1991.

Site (Location)	Date	IBI	Integrity Class
Dry Run (SR 33)	8/15/91	33	Poor
Solomon Creek (CR 146)	8/1/91	40	Fair
Solomon Creek (SR 13/6)	8/15/91	36	Fair-Poor
Solomon Creek (Co. Line Rd.)	7/10/91	40	Fair
Solomon Creek (CR 450 N)	7/10/91	38	Fair-Poor

Natural Communities and Endangered, Threatened, and Rare Species

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, or rare species, high quality natural communities, and natural areas in Indiana. The database was developed to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the Indiana Department of Natural Resources (IDNR). Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of a species or natural area does not guarantee that the listed species is present or that the listed area is in pristine condition. To assist users, the database includes the date that the species or special habitat was last observed and reported in a specific location.

Results from the database search for the Whetten Ditch, Solomon Creek, and Dry Run Watersheds are presented in Appendix 4. (For additional reference, a listing of endangered, threatened, and rare species documented in Elkhart, Kosciusko, and Noble Counties is included in Appendix 5). According to the database, the study watershed supports four high quality community types within the study area: upland mesic forest, sedge meadow wetland at the Engle Lake Marsh, acid bog wetland at the Paul Thomas Memorial Bog, and shrub swamp wetland also at the Paul Thomas Bog Site. The Paul Thomas Memorial Bog Site is located near the southern edge of the watershed and is home to bog rosemary (*Andromeda glaucophylla*), a rare species in Indiana, and small cranberry (*Vaccinium oxycoccos*), a state threatened species. State rare and endangered plants Hickey's clubmoss (*Lycopodium hickeyi*), tree clubmoss (*Lycopodium obscurum*), and wild calla (*Calla palustris*) have been documented at the Merry Lea Environmental Center which is also near the southern edge of the study area. Hickey's clubmoss has also been found near Worley Ditch at the Ruckstuhl Site. The database also lists sitings of the state endangered American badger (*Taxidea taxus*) in the area. The blue heron (*Ardea herodias*) and the Baltimore insect (*Euphydryas phaeton*) are species associated with high quality natural areas and have been documented just north of Lake Wawasee near Meyer Ditch.

WATERSHED STUDY

The watershed study is composed of two main components: the watershed investigation and the stream sampling and assessment. The watershed investigation entailed both an aerial tour and a windshield survey of the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. The stream sampling and assessment involved: 1) stream water quality sampling at nine sites during base flow and during stormwater runoff; 2) a Qualitative Habitat Evaluation Index (QHEI) calculation for all nine sites; and 3) a macroinvertebrate Index of Biotic Integrity (mIBI) calculation for each stream sampling site.

Watershed Investigation

Introduction

Targeting areas of concern and selecting sites for future management are the goals of a visual watershed inspection. The study area watersheds were toured by airplane in April of 2001 and a windshield survey was conducted in early December of 2001 after most crops were removed. The results of and observations made during these two surveys are presented below. Figure 22 offers a summary of observations made during the both the aerial tour and the windshield survey.

Aerial Tour

The aerial tour consisted of flying over the watershed at fairly low altitudes in order to photograph high priority and environmentally sensitive areas. Areas of concern with corresponding aerial photos are discussed by subwatershed, and their locations are mapped on Figure 22. Photos of unique problems are included in the discussion of each subwatershed.

Whetten Ditch Subwatershed. Photos taken of the Whetten Ditch Subwatershed were not detailed enough to discern individual problems. For this reason, additional time was spent in the Whetten Ditch area during the windshield watershed tour. Whetten Ditch will be discussed in more detail in the Windshield Tour Section.

Solomon Creek West Subwatershed. Table 34 contains data relevant to 17 sites in the Solomon Creek West Subwatershed where land management actions could improve water quality (Sites A1-17; Figure 22). Most photos taken in the Solomon Creek West Subwatershed document a practice that is generally typical in the study watershed: farming at or very near the stream's edge as shown in the representative photo in Figure 23. Such situations are ideal candidates for filter strip installation. Remnant wetlands and hydric soils were evident at Sites A1 and A14 (Figure 24) where wetland restoration could be possible. Restored wetlands increase water holding/storage capacity in the watershed, thereby reducing runoff volumes during storm events. Large, uncontrolled runoff events can cause soil and bank destabilization and erosion. Wetlands also offer mechanical and biological filtration of water that effectively removes sediment, pathogens, nutrients, and other chemicals from runoff. Based on tracks made by the center pivot irrigation tires at Site A9, land very close to the stream's edge was regularly irrigated (Figure 25). Irrigation practices should be backed away from stream banks, and filter strips should be installed at this location. Although no livestock is evident in the Site A13 photo, stream banks and surrounding land appears to have been heavily grazed (Figure 26). Livestock should be fenced away from streams and riparian areas.

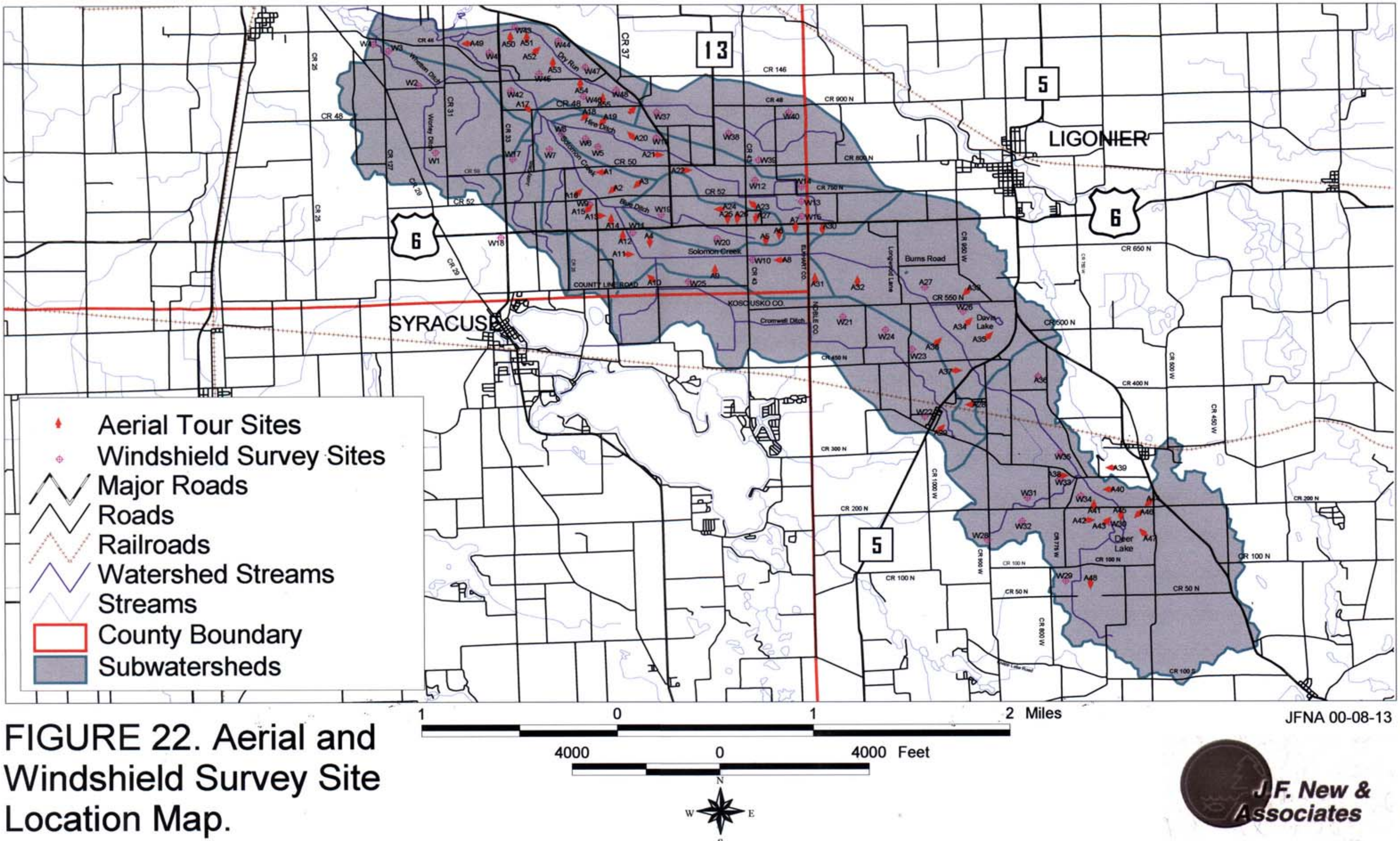


FIGURE 22. Aerial and Windshield Survey Site Location Map.

TABLE 34. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Solomon Creek West Subwatershed. Causes of impairment and practices that could be used to treat them are also listed. Sites A1-17 are located on the mainstem of Solomon Creek.

Site	Cause	Management Practice
A1	NA	Wetland restoration is possible
A2	Land is farmed to stream's edge	Filter strips
A3	Land is farmed to stream's edge	Filter strips
A4	Land is farmed to stream's edge	Filter strips
A5	Land is farmed to stream's edge	Filter strips
A6	Land is farmed to stream's edge	Filter strips
A7	Land is farmed to stream's edge	Filter strips
A8	Banks are eroding	Allow for natural riparian vegetation growth
A9	Irrigation at stream's edge; land is farmed to stream's edge	Back irrigation away from stream; filter strips
A10	Land is farmed to stream's edge	Filter strips
A11	Land is farmed to stream's edge	Filter strips
A12	Land is farmed to stream's edge	Filter strips
A13	Banks are eroding; the site appears to have been heavily grazed	Allow for natural riparian vegetation growth; fence livestock from stream area
A14	Land is farmed to stream's edge	Filter strips; wetland restoration is possible
A15	Banks are eroding; land is farmed to stream's edge	Bank stabilization; filter strips
A16	Banks are eroding; land is farmed to stream's edge	Bank stabilization; filter strips
A17	Land is farmed to stream's edge	Filter strips

NA = Not applicable

FIGURE 23. Representative photo of filter strip deficiency along a stream in the study area.

FIGURE 24. Site A1 showing potential wetland restoration sites in the Solomon Creek West Watershed.

FIGURE 25. Site A9 showing irrigation adjacent to the ditch bank.

FIGURE 26. Site A13 showing stream banks that appear to have been heavily grazed and could benefit from riparian area fencing.

Hire Ditch Subwatershed. Six potential management practice locations were documented during the aerial tour in the Hire Ditch Subwatershed (Sites A18-23; Table 35; Figure 22). Three of the areas would benefit from filter strip or other agricultural practice set-back zone. Livestock set-back zones could also be implemented at Site A18 where banks and riparian areas appeared to have been overgrazed. The area at Sites A19 and A20 would offer an outstanding wetland restoration site. As shown in Figure 27, the farmer is growing crops among six narrowly spaced drainage ditches in this area, evidence that hydrology would support wetland restoration.

TABLE 35. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Hire Ditch Subwatershed. Causes of impairment and practices that could be used to treat them are also listed. Sites A18-23 are located on Hire Ditch, a tributary of Solomon Creek.

Site	Cause	Management Practice
A18	The site appears to have been heavily grazed; riparian vegetation had been destroyed	Allow for natural riparian vegetation growth; fence livestock from stream area
A19	NA	Wetland restoration is possible
A20	NA	Wetland restoration is possible
A21	Land is farmed to stream's edge	Filter strips
A22	Land is farmed to stream's edge	Filter strips
A23	Land is farmed to stream's edge	Filter strips

FIGURE 27. Potential wetland restoration site (Site A19) in the Hire Ditch Subwatershed.

Juday Ditch Subwatershed. As was the case with photos of the Whetten Ditch Subwatershed, aerial photos of the Juday Ditch Subwatershed did not offer enough detail for problem or resource analysis. Juday Ditch will be discussed in more detail in the Windshield Tour Section.

Blue Ditch Subwatershed. Producers were farming land up to or very near the ditch's banks at all four documented sites in the Blue Ditch Subwatershed (Sites A24-27; Table 36; Figure 22). Water quality in Blue Ditch could be improved by filter strip installation and riparian protection.

TABLE 36. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Blue Ditch Subwatershed. Causes of impairment and practices that could be used to treat them are also listed. Sites A24-27 are located on Blue Ditch, a tributary of Solomon Creek.

Site	Cause	Management Practice
A24	Land is farmed to stream's edge	Filter strips
A25	Land is farmed to stream's edge	Filter strips
A26	Land is farmed to stream's edge	Filter strips
A27	Land is farmed to stream's edge	Filter strips

Meyer/Cromwell Ditch Subwatershed. Much of the Meyer/Cromwell Ditch Subwatershed was not captured in photos taken during the aerial tour. For this reason, it received more attention during the driving tour and will be discussed in the Windshield Tour Section. Two photos (Sites A28 and 29; Figure 22) did capture the town of Cromwell and two attributes that may have implications for water quality in Solomon Creek. Site A28 (Figure 28) clearly shows a sizable mobile home and trailer park on the north side of Cromwell. Although not within Cromwell city limits, waste effluent from the development is routed to the Cromwell wastewater treatment plant (WWTP) according to the superintendent of the plant (Bob Lemon, personal communication). The Cromwell WWTP (Site A29; Figure 29) discharges to Cromwell Ditch, was toured during the windshield survey, and will be discussed in more detail in the Windshield Survey Section.

FIGURE 28. Site A28 showing the mobile home and trailer park on the north side of Cromwell.

FIGURE 29. Site A29 showing the Cromwell WWTP.

Solomon Creek East Subwatershed. Many sites (A31, A32, and A37) in the Solomon Creek East Subwatershed would benefit from riparian vegetation growth that will occur naturally if livestock are excluded and herbicides are not applied. The CRP filter strip was evident at Sites A31 and A32, but some channel instability was still noticeable (Figure 30). Three locations within the Solomon Creek East Subwatershed would also be suited to wetland restoration activities (Sites A33, A35, and A36; Table 37; Figure 22). Sites A33 and A35 are near Davis Lake where there was also evidence of some new residential development (Figure 31). A vehicle scrap-yard was documented near the stream at Site A30 (Figure 32). This study did not focus on possible scrap-yard impacts on water quality, but the location of the scrap-yard is noteworthy since leaking oil and grease constituents can affect surface and ground water quality. Finally, Sites A34, A35, and A36 could be treated with filter strip set-backs.

TABLE 37. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Solomon Creek East Subwatershed. Causes of impairment and practices that could be used to treat them are also listed. Sites A30-32 and A36-37 are located on the mainstem of Solomon Creek, while Sites A33-35 are located on the Davis Lake tributary to Solomon Creek.

Site	Cause	Management Practice
A30	NA	Ensure that oil and grease constituents are not reaching surface or ground water
A31	Banks are eroding	Allow for natural riparian vegetation growth
A32	The site appears to have been grazed; riparian vegetation had been destroyed	Allow for natural riparian vegetation growth; fence livestock from stream area
A33	NA	Wetland restoration is possible
A34	Land is farmed to stream's edge	Filter strips
A35	Land is farmed to stream's edge	Wetland restoration is possible; at the very minimum filter strips should be installed
A36	Land is farmed to stream's edge	Wetland restoration is possible; at the very minimum filter strips should be installed
A37	Riparian vegetation had been destroyed	Allow for natural riparian vegetation growth

FIGURE 30. CRP filter strip at Site A32 in the Solomon Creek East Subwatershed. In spite of the filter strip, some bank erosion is still evident.

FIGURE 31. Site A35 showing some new residential development in the Solomon Creek East Subwatershed.

FIGURE 32. Vehicle scrap-yard near Solomon Creek (Site A30).

Solomon Creek Headwaters Subwatershed. Several locations within the Solomon Creek Headwaters Subwatershed are being farmed up to the stream's edge and need filter strip set-back areas (Sites A38, A39, A40, A41, A43, A44, A46, and A48; Table 38; Figure 22). According to FSA records, ditch banks at Site A43 are currently enrolled in CRP; however, little evidence of a filter strip set-back existed (Figure 33). The landowner at the location had tilled up to the stream's edge. The tracts of land adjacent to small ditches at Site A48 all lack filter strips and are all located on highly erodible land. These areas should be prioritized for filter strip installation. Sites A42 and A45 offer wetland restoration potential. Restored wetlands on Deer Lake (Site A45) would be particularly beneficial for the entire Solomon Creek Watershed. Because Deer Lake is near the headwaters, wetlands could store runoff during storms preventing the large volumes of rapidly moving runoff from causing stream bank erosion downstream. The aerial photo of Site A47 (Figure 34) shows the installation of a new tile system to drain water to Deer Lake. Projects like these cause disturbance in the watershed and contribute to water quality impairment. These types of projects should only be undertaken if absolutely necessary. Landowners should be informed of the ramifications of such projects and alternative solutions should be discussed and considered.

TABLE 38. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Solomon Creek Headwaters Subwatershed. Causes of impairment and practices that could be used to treat them are also listed. All sites except Site A48 are located on the mainstem of Solomon Creek. Site A48 includes many small, unnamed ditches that feed into Solomon Creek.

Site	Cause	Management Practice
A38	Land is farmed to stream's edge	Filter strips
A39	Land is farmed to stream's edge	Wetland restoration is possible; at the very minimum filter strips should be installed
A40	Land is farmed to stream's edge	Filter strips
A41	Land is farmed to stream's edge	Filter strips
A42	NA	Wetland restoration is possible
A43	Land is farmed to stream's edge	Filter strips
A44	Land is farmed to stream's edge	Filter strips
A45	NA	Wetland restoration is possible
A46	Land is farmed to stream's edge	Filter strips
A47	Installation of new tile system to drain land to Deer Lake	Inform landowners of the adverse effects such projects can have for water quality
A48	Land is farmed to stream's edge on several small ditches on HEL	Filter strips

FIGURE 33. Site A43 showing lack of filter strips.

FIGURE 34. New tile installation at Site A47 in the Solomon Creek Headwaters Subwatershed.

Dry Run Subwatershed. Aerial photography taken in the Dry Run Subwatershed also did not allow for enough detail for analysis of areas of concern that may merit management. Therefore, this area received added attention during the windshield survey and will be discussed further in the Windshield Survey Section.

Mouths of Solomon Creek and Dry Run Subwatershed. Several areas in the Mouths of Solomon Creek and Dry Run Subwatershed could be targeted for BMP installation based on photos from the aerial tour (Table 39; Figure 22). Typical BMPs like filter strip projects would greatly reduce soil loss from tracts within this subwatershed. Figure 35 (Site A50) shows a new residential development. Developers in the area should be encouraged to experiment with conservation design when planning new development areas. Conservation design results in preservation of open space by clustering houses close together. Less pavement and impervious surfaces are necessary, and homeowners can share the open spaces for gardens, sports fields, and wildlife areas. (These open spaces are much larger than those afforded by individual lawn areas.)

TABLE 39. List of impaired locations or locations where management applications are relevant as photographed during the aerial tour of the Mouths of Solomon Creek and Dry Run Subwatershed. Causes of impairment and practices that could be used to treat them are also listed. All sites except Site A48 are located on the mainstem of Dry Run.

Site	Cause	Management Practice
A49	Land is farmed to stream's edge	Filter strips
A50	Land is farmed to stream's edge; a sprawling subdivision with large amounts of impervious surfaces has been recently constructed	Filter strips; conservation design development for future developments of this type
A51	Land is farmed to stream's edge	Filter strips
A52	Land is farmed to stream's edge	Filter strips
A53	Land is farmed to stream's edge	Filter strips
A54	Land is farmed to stream's edge	Filter strips
A55	Land is farmed to stream's edge	Filter strips
A56	Land is farmed to stream's edge	Filter strips

FIGURE 35. New residential development at Site A50 in the Mouths of Solomon Creek and Dry Run Subwatershed.

Windshield Tour

Introduction

The windshield survey was conducted on December 4, 2001 and entailed driving the watersheds and assessing the streams where they crossed or were located adjacent to roads. Beverly Stevenson and Nancy Brown of the Elkhart County SWCD participated in the tour. Particular areas of concern were examined more closely by stopping and walking areas within public right-of-way. Some facilities like the Maple Leaf Duck Farm Hatchery and the Cromwell Waste Water Treatment Plant (WWTP) were toured as well.

Observations made during the windshield tour fall into two different classes: those relating to sites having potential for best management practice implementation (like fields bordering streams and needing filter strips) and those relating to sites or operations which may contribute point or non-point source pollution to the streams (like the Cromwell WWTP). These two classes are discussed below and their locations appear on Figures 36 and 22.

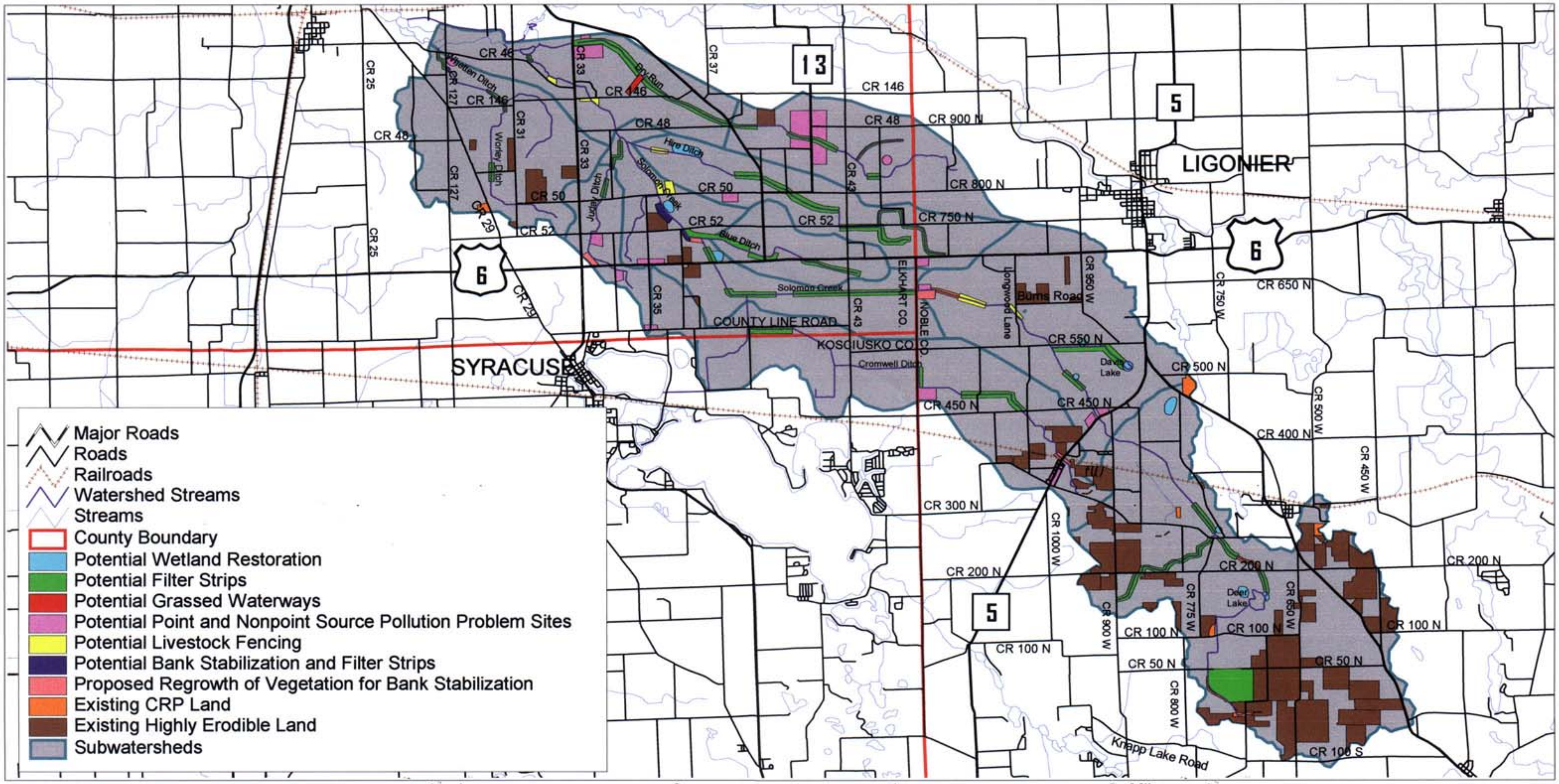


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FIGURE 36. Management Recommendations and Potential Point and Nonpoint Source Location Map.

Sites for Potential Management Practice Implementation

Most observations made during the windshield tour relate to needs for better management practice implementation in the study areas. Table 40 lists all sites where BMPs could benefit water quality by number and by subwatershed and lists any corresponding photos that were taken of each site while on the tour. Site locations are displayed in Figure 22, and photos appear in Figures 37-39.

TABLE 40. List of sites and corresponding BMPs compiled during the windshield survey portion of the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

Subwatershed	Site	Recommended BMP
Whetten Ditch	W1	Enlarge filter strip width
Whetten Ditch	W2	Filter strips
Whetten Ditch	W3	Bank stabilization (see photo in Figure 37)
Whetten Ditch	W4	Filter strips
Solomon Creek West	W5	Fence hogs from wetland that drains into Solomon Creek
Solomon Creek West	W6	Install filter strip or buffer area between hog pen and creek or move hog pen further from creek
Solomon Creek West	W7	Filter strips
Solomon Creek West	W8	Filter strips
Solomon Creek West	W9	Install filter strip or buffer area between pasture and stream
Solomon Creek West	W10	Filter strips
Solomon Creek West	W11	Filter strips
Hire Ditch	W12	Filter strips (see photo in Figure 38)
Hire Ditch	W13	Filter strips
Hire Ditch	W14	Widen existing narrow filter strips
Hire Ditch	W15	Widen existing narrow filter strips
Hire Ditch	W16	Filter strips
Juday Ditch	W17	Filter strips
Juday Ditch	W18	Revegetate drainage swale area and surrounding low ground
Blue Ditch	W19	Widen existing narrow filter strips
Blue Ditch	W20	Filter strips
Meyer/Cromwell Ditch	W21	Filter strips
Meyer/Cromwell Ditch	W22	Revegetate exposed areas
Meyer/Cromwell Ditch	W23	Widen existing narrow filter strips
Meyer/Cromwell Ditch	W24	Filter strips
Meyer/Cromwell Ditch	W25	Filter strips
Solomon Creek East	W26	Filter strips
Solomon Creek East	W27	Fence livestock from stream (see photo in Figure 39)
Solomon Creek Headwaters	W28	Filter strips
Solomon Creek Headwaters	W29	According to FSA records, a segment of this HEL tract is in CRP, but no evidence of a CRP set-aside exists at the site
Solomon Creek Headwaters	W30	Filter strips

Solomon Creek Headwaters	W31	Filter strips
Solomon Creek Headwaters	W32	Filter strips
Solomon Creek Headwaters	W33	Filter strips and bank stabilization
Solomon Creek Headwaters	W34	Filter strips
Solomon Creek Headwaters	W35	Filter strips
Solomon Creek Headwaters	W36	Potential for wetland restoration exists at this site
Dry Run	W37	Filter strips
Dry Run	W38	Filter strips
Dry Run	W39	Filter strips
Dry Run	W40	Filter strips
Mouths of Solomon Creek and Dry Run	W41	SWCD is already working on a manure pad and dry stacking but more work still needs to be done; livestock needs to be fenced from stream
Mouths of Solomon Creek and Dry Run	W42	Fence livestock from stream
Mouths of Solomon Creek and Dry Run	W43	Filter strips
Mouths of Solomon Creek and Dry Run	W44	Filter strips
Mouths of Solomon Creek and Dry Run	W45	Grassed waterway
Mouths of Solomon Creek and Dry Run	W46	Filter strips
Mouths of Solomon Creek and Dry Run	W47	Filter strips
Mouths of Solomon Creek and Dry Run	W48	Filter strips

FIGURE 37. Site W3 taken during the windshield survey showing sediment deposition and bank erosion in the Whetten Ditch Subwatershed.

FIGURE 38. Site W12 taken during the windshield survey showing unstable banks and the need for filter strips in the Hire Ditch Subwatershed.

FIGURE 39. Site W27 taken during the windshield survey showing a need for livestock fencing in the Solomon Creek East Subwatershed.

<u>Potential Contributors of Point or Non-Point Source Pollution</u>

Some observations made during the windshield survey revealed operations that may contribute to water pollution in more direct ways. Because no data was collected during this study to test effluent or runoff from any of the following facilities or operations, it was not possible to determine if or to what extent their activities may contribute to water pollution. The current study documented their existence and location and recognized their potential to contribute to either point or non-point source pollution.

Whetten Ditch Subwatershed. Based on observations made during the windshield tour, there are no livestock operations in the Whetten Ditch Subwatershed; however, the New Paris Speedway is located east of CR127 and south of CR46 (Figure 36). Car racing events are held at the location each weekend during the summer months. According to the Elkhart County Surveyor's Office, the Thwaits tile system, which was replaced last year, drains this area to Whetten Ditch. Although no sampling of the tile drain or runoff from this area was conducted during this study, the racetrack may be a contributor of grease and other petroleum-based materials especially during the summer months. Large numbers of race fans utilizing septic facilities at the location may also have implications for water quality.

Solomon Creek West Subwatershed. One dairy is located in the Solomon Creek West Subwatershed near the headwaters of an unnamed tributary to Solomon Creek (Figure 36). Although the number of animals kept at the operation is not known, the dairy appeared to be quite large. A proper manure/waste management plan would help to minimize impacts the dairy may have on water quality.

Hire Ditch Subwatershed. Two scrap yard areas were documented while touring the Hire Ditch Subwatershed (Figure 36). The yard on CR50 is old, and no new refuse is currently being introduced to the site. The yard on US6 remains active. While scrap yard impacts to water quality were not measured during this study, their existence and location were documented. Additionally, the Elkhart County Surveyor's Office de-brushed and dredged Hire Ditch from CR 43 east to the county line two years ago. The remaining portion of Hire Ditch from CR 43 west to Solomon Creek has been petitioned for maintenance, and the project is expected to begin within two years.

Juday Ditch Subwatershed. A fish farm is located directly adjacent to Juday Ditch along CR36 (Figure 36). It is now known if the farm has permits for operation and is regulated as a point source by the state. During the watershed tour, a sprinkler system had been set up to water a turf grass area. Runoff from the watered area was flowing down a small roadway swale area and entering Juday Ditch. A hog operation was also noted on the south side of US6 near the headwaters of Juday Ditch (Figure 36).

Meyer/Cromwell Ditch Subwatershed. Several potential point and non-point source contributors were noted during the Meyer/Cromwell Ditch Subwatershed tour: a dairy, a Waste Water Treatment Plant (WWTP), the town of Cromwell, and its composting facility (Figure 36). The dairy is located at the intersection of CR35 and the Elkhart/Kosciusko County Line Road. It appeared to by fairly large in size, but the exact number of animals and its regulatory status are not known. The Turkey Creek WWTP treats sewage from 75% of the homes on Lake Wawasee and all of the trailers in the Enchanted Hills Subdivision (Tim Woodward, sewer district superintendent, personal communication). The Lake Wawasee area is actually part of the Turkey Creek Watershed, but treated effluent discharged from the plant is released into Cromwell Ditch. The plant is permitted as a point source by the state of Indiana. Cromwell is the only incorporated town in the study area. As in most small towns in the Midwest, no infrastructure exists for stormwater treatment. During rain events, catch basin collect water and conduct it to underground tiles which carry the water directly to Cromwell Ditch. Additionally, the town of Cromwell had recently set up a yard waste composting area on the northeast bank of Cromwell Ditch. Although a composting facility certainly provides many benefits, its proximity to the ditch may result in the introduction of partially decomposed organic matter and nutrients.

Solomon Creek East Subwatershed. The Solomon Creek East Watershed contains two state-permitted point sources of pollution: the Cromwell WWTP and the Maple Leaf Duck Farms Hatchery. The Cromwell WWTP treats waste effluent from the town of Cromwell and a trailer park which lies just outside the northwest incorporated city limits. The plant serves about 1,300 local resident and the Maple Leaf Duck Farms Hatchery. According to Dan Harper of Maple Leaf Duck Farms, infertile eggs and other biological wastes are also routed to the WWTP. Treated water is discharged to Solomon Creek. During the watershed tour, Clark Reed the plant superintendent stated that permits allowing for sludge spreading had accidentally been violated due to calculation error, and nitrogen in sludge had been over-applied by nearly four times the rate allowed by the permit (150 lbs N/acres). Permits for sludge application are based solely on soil and sludge nitrogen (total Kjeldahl nitrogen, nitrate, and ammonia) content. Additionally, discharge water is not treated for pathogen removal from April 1st to November 1st. Clark Reed admitted that even when effluent is sterilized during the summer months, *E. coli* tests are often above the 260 col/100 ml required by his permit. Additional problems occur in spring and fall during cold spells when bacterial cultures die back and fail to remove sufficient quantities of nitrate and ammonia from the wastewater. Permits for effluent discharge are only based on nitrogen loads and do not require testing for phosphorus or calculation of phosphorus loading to the stream. Based on these observations, the Cromwell WWTP is probably a significant nutrient and bacteria source especially during the spring and fall. Directly across Solomon Creek from the Cromwell WWTP, Maple Leaf Duck Farms operates a duckling hatchery. The hatchery incubates eggs for 28 days until hatching when they are transported to smaller rearing facilities in the area. Cold well water is used to cool the incubation tanks. Once the water has received a permitted amount of heat, it is discharged to Solomon Creek.

Dry Run Subwatershed. A hog operation and a cellular phone tower construction project were noted as potential pollution sources in the Dry Run Subwatershed (Figure 36). The hog operation on SR13 appeared large in size, and the producer irrigates the fields to which manure is also applied. Because it is often difficult to prevent soil erosion during construction, it is possible that the tower construction project resulted in some sediment and sediment-attached nutrient loading to Dry Run.

Mouths of Solomon Creek and Dry Run Subwatershed. Another construction project was underway at or in the vicinity of the Mouths of Solomon Creek and Dry Run Subwatershed (Figure 36). The Dry Run Creek Subdivision is currently being developed on CR33 along the stream. This is the same development photographed during the aerial tour (Site A50). Developments like these increase the amount of impervious surface near the stream, thereby decreasing runoff infiltration. They also increase nutrient loading to streams due to lawn care practices and septic system use. Development of prime farmland can also result in farming of more marginal areas which can be environmentally detrimental. Conservation development is recommended for future residential projects near the creek. The only beef cattle operation in the study drainage is located on the bank of Dry Run (Figure 36). An animal operation like this one has the potential to impair water quality if manure is not carefully managed.

Permitted Point Source Discharge Compliance Report Discussion

Three separate facilities currently hold permits from the state to discharge specified loads of certain pollutants into streams within the study watershed area. Permitted facilities are required to monitor their discharge and submit compliance reports to the state monthly. A facility that discharges amounts of pollutants that exceed their permitted level are in violation and must correct the problem in a timely manner. The Environmental Protection Agency (EPA) Envirofacts Warehouse on-line database can be queried to determine if certain facilities consistently meet or violate standard criteria set for discharge effluent. The Envirofacts database website is located at http://www.epa.gov/enviro/html/pcs/pcs_overview. Additional information pertaining to NPDES permits, permit compliance, and permit violations may be obtained from IDEM. (Catherine Hess handles municipal discharge permits and may be contacted at (317) 232-8704. Steve Rouch oversees industrial discharge permits; his telephone number is (317) 232-8706. The IDEM file room stores all permit-related records and can be reached at (317) 234-0111.)

The Turkey Creek Regional Sewer District treats wastewater from the Lake Wawasee area and currently holds a permit to discharge treated water into Cromwell Ditch. The plant is located at 4852 N 1200 W. Discharge water is monitored for dissolved oxygen (DO), pH, total suspended solids (TSS), ammonia nitrogen (NH_3-N), *E. coli*, ultra-violet light intensity, flow, carbonaceous biological oxygen demand (C-BOD), percent C-BOD removed, and percent suspended solids removed. Table 41 lists the number of times and the percentage of the time that the Turkey Creek Regional Sewer District was in violation of its permit for chemical parameters from January 1998-September 2001. The parameter of greatest concern was *E. coli* concentration in treated effluent. When in violation, the plant reported maximum *E. coli* concentration ranging from 256-2830 col/100 ml. The majority of *E. coli* violations occurred during late spring, summer, and early fall months, and the Turkey Creek Regional Sewer District was in violation of its permitted *E. coli* level in 44% of the samples taken from January 1998 to September 2001.

TABLE 41. Number of times and percentage of time Turkey Creek Regional Sewer District was in violation of its permit for chemical discharge from January 1998-September 2001.

Parameter	Number of Times Violation Occurred	% of Time Plant was in Violation
DO	1	2.2%
pH	1	2.2%
TSS	3	6.5%
NH_3	5	10.9%
E. coli	19	44.2%
C-BOD	1	2.2%

Source: EPA's Envirofacts Warehouse database.

The Cromwell Municipal Sewer Treatment Plant (STP) located at 4142 North State Road 5 also currently holds a permit to discharge by-products of municipal waste treatment to Solomon

Creek. Treatment effluent must meet certain standards for: DO, pH, TSS, NH_3-N, *E. coli*, ultra-violet light intensity, flow, and C-BOD. Table 42 contains data similar to that reported for the Turkey Creek Regional Sewer District in Table 41. The Cromwell STP was in violation of its discharge limits for *E. coli*, DO, and NH_3-N during >15% of the months when samples were taken. Maximum concentrations of *E. coli* in violation ranged from 264-7040 col/100 ml, while maximum ammonia concentrations in violation ranged from 1.76-13 mg/l.

TABLE 42. Number of times and percentage of time Cromwell Municipal STP was in violation of its permit for chemical discharge from April 1999-July 2001.

Parameter	Number of Times Violation Occurred	% of Time Plant was in Violation
DO	5	18.5%
pH	1	3.6%
TSS	1	3.6%
NH_3	6	21.4%
E. coli	5	29.4%
C-BOD	0	0.0%

Source: EPA's Envirofacts Warehouse database.

Because the Maple Leaf Farms Hatchery located at 4379 N 900 W discharges well water that is used to cool incubation equipment, the hatchery monitors temperature, pH, oil/grease/freon, and flow. Since January of 1999, the hatchery has only violated permitted discharge limits once. In January of 1999, about twice the permitted concentration of oil/grease/freon was discharged to Solomon Creek.

Watershed Investigation Conclusion

The goal of the watershed investigation was to target areas of concern and select sites for future management. Locations identified during both the aerial windshield tours where certain land use management practices are relevant and applicable appear in Figure 36. The aerial tour pointed out areas where filter strip implementation and livestock fencing could benefit water quality especially in the Solomon Creek West, Hire Ditch, Solomon Creek East, Mouths of Solomon Creek and Dry Run, and Solomon Creek Headwaters Subwatersheds. Areas for wetland restoration in the Solomon Creek West, Hire Ditch, Solomon Creek East, and Solomon Creek Headwaters Subwatersheds were also noted from the air. Additional areas for BMP implementation were documented during the windshield survey including opportunities for: filter strip application, bank stabilization, livestock fencing, revegetation of eroded/disturbed areas, grassed waterway application, and wetland restoration. The windshield tour also revealed one area where land enrolled in the CRP showed little or no evidence of actual BMP installation or program participation. This is of concern and should warrant further investigation. Several potential contributors to point and/or non-point source pollution were also documented during the windshield tour. No sampling was conducted to determine pollutant contribution, but potential sources included: a motorcar racetrack, two dairies, a fish farm, two hog operations, two WWTPs, the town of Cromwell, a duck farm hatchery, a beef operation, and a new subdivision. According to Permit Compliance System data, both of the WWTPs in the watershed frequently violate their permits and discharge higher concentrations of pollutants than allowed, particularly *E. coli* concentrations.

Stream Sampling and Assessment

Introduction

The stream assessment portion of the watershed study consisted of water chemistry sampling during base flow and during a storm runoff event, a macroinvertebrate community assessment, and a habitat assessment. Sampling was conducted at 9 sites in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds (Figure 40). The stream assessment study provides information that can be analyzed to determine water quality and aquatic habitat impairment. The data can be used to guide a prioritization of management actions and direct those actions toward the most critical areas.

Sampling Locations

Nine sampling sites were strategically chosen throughout the Whetten Ditch, Solomon Creek, and Dry Run Watersheds (Figure 40; Table 43). The sites were selected based on accessibility and relative amount of information that could be obtained for each subwatershed. Ideally, the sampling protocol would include sampling of a reference site for comparative purposes. An ideal reference site would have a relatively undisturbed watershed with little channel alteration and would meet all criteria listed in Table 44. However, because of extensive human activities throughout the watersheds in the study area, a reference site meeting all of the criteria in Table 44 could not be located.

State personnel have suggested two streams that offer potential for use as reference sites: Stoney Creek near Muncie, Indiana and Otter Creek near Terre Haute, Indiana. However, neither of these two streams is located within the same ecoregion as the study area. Because of their location within difference ecoregions, the relevance of comparing Stoney or Otter Creeks with Whetten Ditch, Solomon Creek, or Dry Run is limited.

TABLE 43. Detailed sampling location information for the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

Site #	Stream Name	Related Subwatershed	Road Location	Place Sampled	Latitude	Longitude
1	Whetten Ditch	Whetten Ditch	intersection of CR 46	south side of CR 46	N41°29.908	W85°47.487
2	Solomon Creek	Solomon Creek West	intersection of CR 146	north side of CR 146	N41°29.272	W85°44.859
3	Hire Ditch	Hire Ditch	farm off of CR 48	upstream of culvert on Yoder farm property	N41°28.163	W85°43.949
4	Juday Ditch	Juday Ditch	intersection of CR 133	west side of CR 133	N41°28.330	W85°44.482
5	Blue Ditch	Blue Ditch	south of CR 52	upstream of confluence with Solomon Creek	N41°27.402	W85°43.078
6	Solomon Creek	Meyer/Cromwell Ditch	farm off of CR 137	on Brown farm	N41°26.627	W85°42.407
7	Solomon Creek	Solomon Creek East	intersection of CR 45 (CR 1000 Kosciusko Co.)	northwest side of CR 45	N41°26.386	W85°35.21.8
8	Solomon Creek	Solomon Creek Headwaters	intersection of Noble Co. CR 900 W	northwest side of CR 900 W	N41°24.314	W85°21.571
9	Dry Run	Dry Run	intersection of US 33	east side of US 33	N41°28.887	W85°42.401

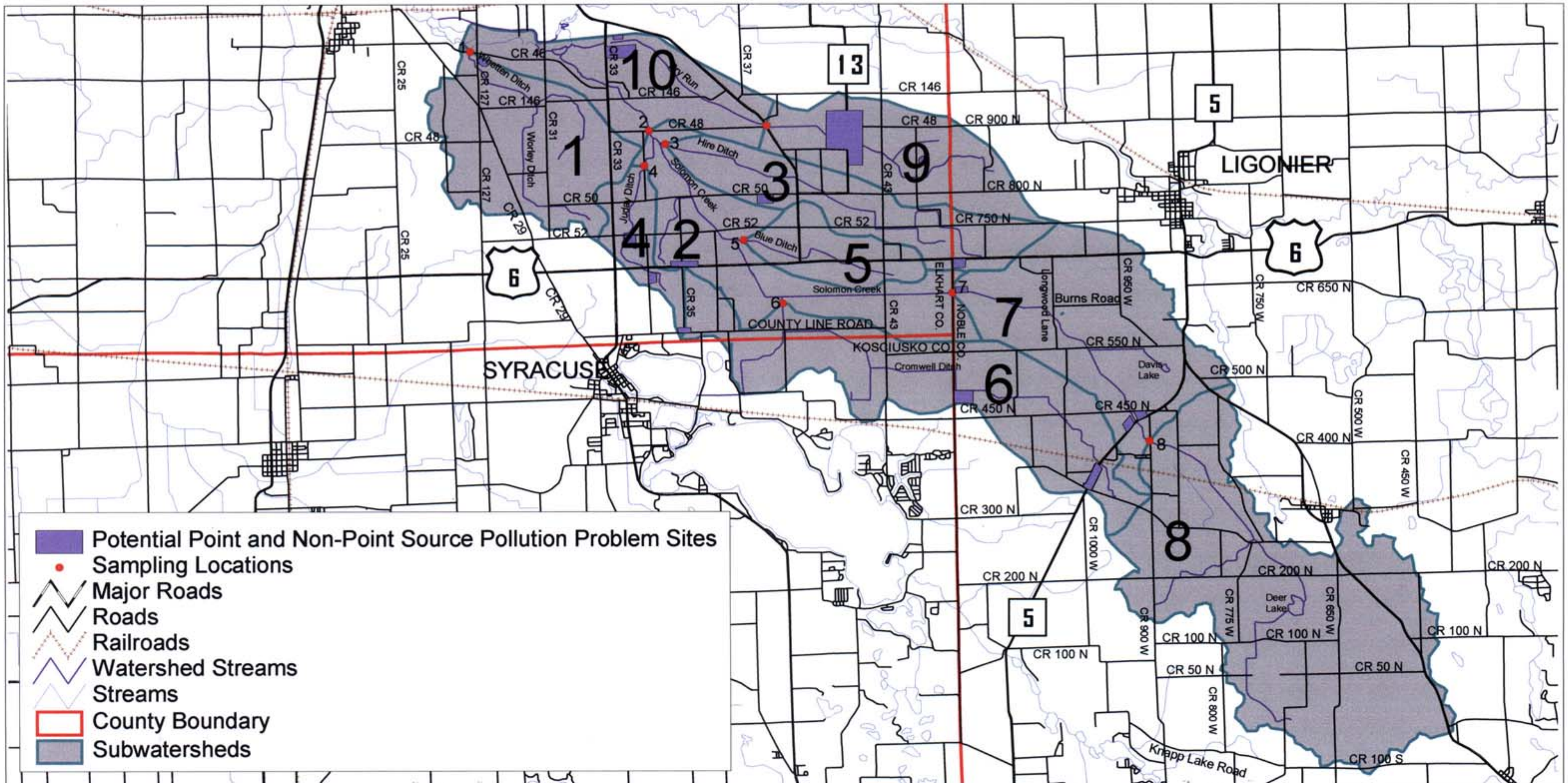

FIGURE 40. Sampling Locations and Potential Point and Nonpoint Source Location Map.

1 0 1 2 Miles

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TABLE 44. Minimum criteria for stream reference sites. Source: Plafkin et al., 1999.

Example Criteria for Reference Sites (Must meet all criteria)
• **pH >=6; if blackwater stream, then pH <=6 and DOC >8 mg/l** • **Dissolved Oxygen >= 4 ppm** • **Nitrate <=16.5 mg/l** • **Urban land use <=20% of catchment area** • **Forest land use >=25% of catchment area** • **Instream habitat rating optimal or suboptimal** • **Riparian buffer width >=15m** • **No channelization** • **No point source discharges**

Water Chemistry

Water Chemistry Methods

The LARE sampling protocol requires assessing water quality of each stream site once during base flow and once during storm flow. A base flow sampling provides an understanding of typical conditions in the streams. Following storm events, the increased overland water flow results in increased erosion of soil and nutrients from the land. Thus, stream concentrations of nutrients and sediment are higher following storm events. In essence, storm sampling presents a "worst case" picture of watershed pollutant loading. The storm event samples were taken on May 16, 2001 following a storm that dumped almost three inches of rain on the watershed during a period of 48 hours, constituting a one-year storm event. Due to the magnitude of the storm event, the soils were likely saturated at the time of sampling. The base flow samples were collected on June 27, 2001 following a period of little precipitation. Although river stage on the Elkhart River on this date exceeded the historical median daily stream flow (Figure 41), the sampling date is representative of base flow because the smaller watershed of Solomon Creek responds more rapidly to flows than does the much larger Elkhart River. It is important to note that even though these results provide insight into the characteristics of the streams at the time of sampling, it is difficult to extrapolate these results to other times of the year and different conditions.

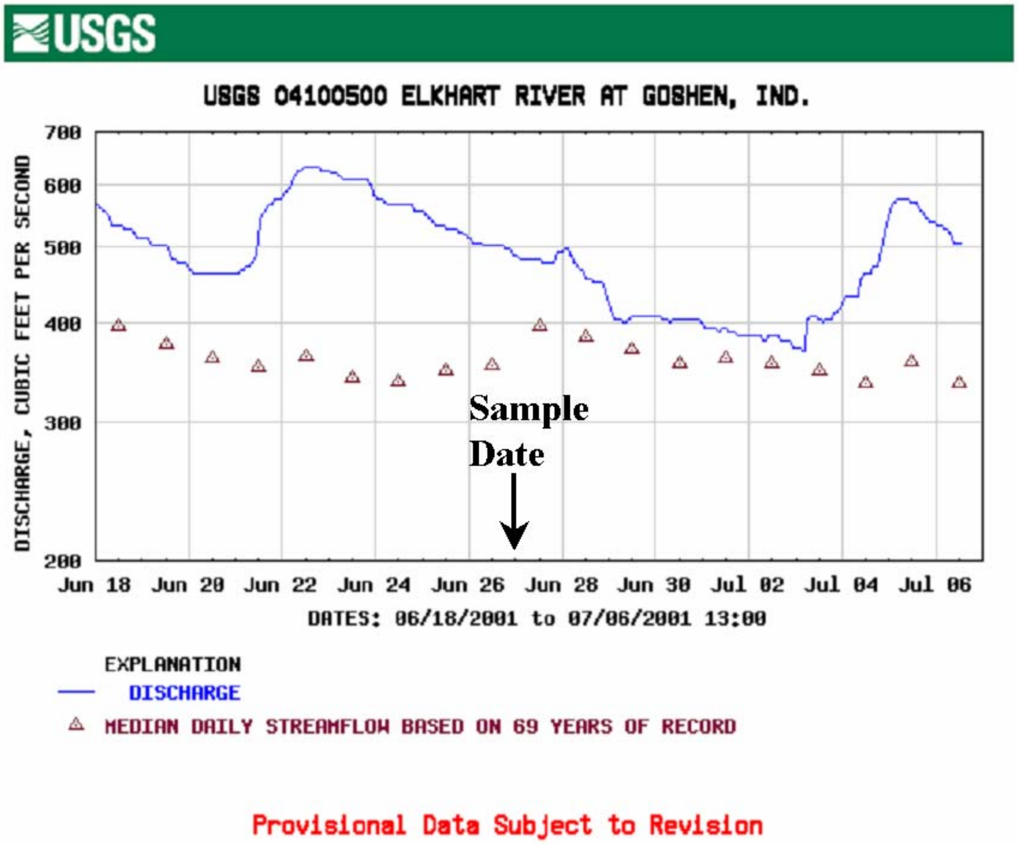

FIGURE 41. Mean daily discharge for the Elkhart River with base flow sampling date noted. Discharge on the sampling date exceeded the 69-year median stream flow.

Base flow and stormwater runoff sampling included measurements of physical, chemical, and bacteriological parameters. Conductivity, temperature, and dissolved oxygen were measured *in situ* using a YSI Model 85 meter. (Alkalinity was measured during base flow only.) Water velocity was measured using a Marsh-McBirney Flo-Mate current meter. Cross-sectional area of the stream channel was measured, and discharge was calculated by multiplying water velocity by cross-sectional area. In addition, water samples were collected from just below the water surface using a cup sampler and tested for:

- pH
- alkalinity (during base flow only)
- turbidity
- total Kjeldahl nitrogen (TKN)
- ammonia-nitrogen (NH_3)
- nitrate-nitrogen (NO_3^-)
- total phosphorus (TP)
- soluble reactive phosphorus (SRP)
- total suspended solids (TSS)
- *E. coli* bacteria

Following collection, samples were stored in an ice chest until analysis either in the Indiana University School of Public and Environmental Affairs (IUSPEA) laboratory in Bloomington (for the base flow samples) or EIS Analytic Services, Inc. in South Bend (for the storm flow samples). All sampling techniques and laboratory analytical methods were performed in accordance with procedures in Standard Methods for the Examination of Water and Wastewater, 19th Edition (APHA, 1995). Appendix 6 provides copies of the laboratory reports for the samples.

The comprehensive evaluation of stream chemistry requires collecting data on the different water quality parameters listed above. A brief description of each parameter follows:

Temperature Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. Likewise, water temperature regulates the species composition and activity of life associated with the aquatic environment. Since essentially all aquatic organisms are 'cold-blooded' the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (EPA, 1976). The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits for Indiana streams. Temperatures during the month of May should not exceed 80°F (23.7°C) by more than 3°F (1.7°C). June temperatures should not exceed 90°F (32.2°C). The Code also states that "the maximum temperature rise at any time or place…shall not exceed 5°F (2.8°C) in streams…".

Dissolved Oxygen (DO) DO is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need at least 3-5 parts per million (ppm) of DO. Coldwater fish such as trout generally require higher concentrations of DO than warmwater fish such as bass or bluegill. The IAC sets minimum DO concentrations at 6 mg/l for coldwater fish. DO enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with DO. Dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1995). During low discharge, conductivity is higher than during storm water runoff because the water moves more slowly across or through ion-containing soils and substrates during base flow. Carbonates and other charged particles dissolve into the slow-moving water, thereby increasing conductivity measurements.

pH The pH of stream water describes the concentration of acidic ions (specifically H^+) present in the water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6-9 pH units for the protection of aquatic life.

Alkalinity Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances, if present in water, like carbonates, bicarbonates, and sulfates can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH. During base flow conditions, alkalinity is usually high because the water picks up carbonates from the bedrock. Alkalinity measurements are usually lower during storm flow conditions because buffering compounds are diluted by rainwater, and runoff water moving quickly across carbonate-containing bedrock materials dissolves little carbonate to add additional buffering capacity.

Turbidity Turbidity (measured in Nephelometric Turbidity Units) is a measure of water coloration and particles suspended in the water itself. It is generally related to suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. According to the Hoosier Riverwatch, the average turbidity of an Indiana stream is 11 NTU with a typical range of 4.5-17.5 NTU (White, unpublished data). Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978).

Nitrogen Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of air is nitrogen gas. This nitrogen can diffuse into water where it can be "fixed", or converted, by blue-green algae for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to aquatic systems. The three common forms of nitrogen are:

Nitrate-Nitrogen (NO_3^--N) – Nitrate is dissolved nitrogen that is converted to ammonia by algae. It is found in streams and runoff when dissolved oxygen is present, usually in the surface waters. Nitrogen applied to farmland is rapidly oxidized or converted to nitrate and usually enters surface and groundwater. Nitrate is highly soluble in water and leaches readily into the groundwater. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams that support modified warmwater habitat (MWH) was 1.6 mg/l. Modified warmwater habitat was defined as: aquatic life use assigned to streams that have irretrievable, extensive, man-induced modifications that preclude attainment of the warmwater habitat use (WWH) designation; such streams are characterized by species that are tolerant of poor chemical quality (fluctuating dissolved oxygen) and habitat conditions (siltation, habitat amplification) that often occur in modified streams (Ohio EPA, 1999). Nitrate-nitrogen concentrations exceeding 10 mg/l in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6).

Ammonia-Nitrogen (NH_3-N) – Ammonia is dissolved nitrogen that is the preferred form for algae use. Bacteria produce ammonia as they decompose dead plant and animal matter. Ammonia is the reduced form of nitrogen and is found where dissolved oxygen is lacking. Both temperature and pH govern the toxicity of ammonia for aquatic life. According to the IAC, maximum unionized ammonia concentrations within the temperature and pH ranges measured for the study streams should range between approximately 0.13 and 0.22 mg/l.

Organic Nitrogen (Org N) – Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. In the analytical procedures, total Kjeldahl nitrogen (TKN) was analyzed. Organic nitrogen is TKN minus ammonia.

Phosphorus Phosphorus is an essential plant nutrient, and the one that most often controls aquatic plant (algae and macrophyte) growth. It is found in fertilizers, human and animal wastes, and yard waste. There are few natural sources of phosphorus to streams other than that which is attached to soil particles, and there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a ***limiting nutrient*** in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Therefore, management efforts often focus on reducing phosphorus inputs to receiving waterways because: (a) it can be managed and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

Soluble reactive phosphorus (SRP) – SRP is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae themselves. Because phosphorus is cycled so rapidly through biota, SRP concentrations as low as 0.005 mg/l are enough to maintain eutrophic or highly productive conditions in lake systems (Correll, 1998). Sources of SRP include fertilizers, animal wastes, and septic systems.

Total phosphorus (TP) – TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.03 mg/l (or 30 μg/l) can cause algal blooms. TP is often a problem in agricultural streams and drainages because TP concentrations for eutrophication control are an order of magnitude lower than those typically measured in soils used to grow crops (0.2-0.3 mg/l). The Ohio EPA (1999) found that the median TP in wadeable streams that support MWH for fish was 0.28 mg/l.

Total Suspended Solids (TSS) A TSS measurement quantifies all particles suspended and dissolved in stream water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in stream water. In general, the concentration of suspended solids is greater during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. Although the State of Indiana sets no standard for TSS, total dissolved solids should not exceed 750 mg/l. In general, TSS >80 mg/l have been found to be deleterious to aquatic life (Waters, 1995).

E. coli **Bacteria** *E. coli* is one member of the fecal coliform bacteria group and is used as an indicator organism to identify the potential for the presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235 col/100 ml in any one sample within a 30-day period. A study conducted by students at IUSPEA in the spring of 2000 found average fecal coliform levels of <200 colonies/100 ml in unglaciated, gravel-bottom creeks in the Stephen's Creek Watershed in Monroe County, Indiana (Klumpp et al., 2000). In general, fecal coliform bacteria have a die-off rate of 90% in 3-5 days (Gerba and McLeod, 1976). However, scientific literature suggests that suspended fine sediment and organic matter particles can result in life expectancy extensions for bacteria (Sherer et al., 1992). Sherer et al. (1992) found that fecal coliform bacteria lived an average of 17 days longer when incubated with sediment. Additionally, benthic sediments can harbor significantly higher concentrations of bacteria than the overlying water, and disturbance of the sediment can result in contamination of the water column.

Water Chemistry Results

Introduction

There are two useful ways to report water quality data in flowing water. *Concentrations* describe the mass of a particular material contained in a unit of water, for example, milligrams of phosphorus per liter (mg/l). *Mass loading* (in units of kg/day) on the other hand describes the mass of a particular material being carried per unit of time. For example, a high concentration of phosphorus in a stream with very little flow will deliver a smaller total amount of phosphorus to the receiving waterway than will a stream with a low concentration of phosphorus but a high flow of water. It is the total amount (mass) of phosphorus, solids, and bacteria actually delivered from the watershed that is the most important when considering the effects of these materials downstream. Because consideration of concentration and mass loading data is important, the following three sections will discuss 1) physical parameter concentrations, 2) chemical and bacterial parameter concentrations, and 3) chemical and sediment parameter mass loading.

Physical Parameter Concentrations

Physical parameter results measured during base and storm flow sampling are presented in Table 45. Stream discharges measured during base and storm flow conditions are shown in Figure 42. Each physical parameter is addressed in the following discussion.

TABLE 45. Physical parameter data collected during stream chemistry sampling events in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds on 5/16/2001 and 6/27/2001.

Site	Date	Timing	Flow (cfs)	Temp °C	D.O. (mg/l)	D.O. Sat. (%)	Cond. (μmhos)	pH	Alk. (mg/l)	Turbidity (NTU)
1	5/16/2001	Storm	26.25	17	7.2	74.5	320	7.2	*	190.0
	6/27/2001	Base	1.50	15	7.81	77.9	505	7.7	255	2.8
2	5/16/2001	Storm	64.32	16.5	7.4	75.8	580	7.4	*	54.0
	6/27/2001	Base	35.68	17.4	7.53	79.1	656	7.9	271	4.8
3	5/16/2001	Storm	9.57	16.4	7.35	75.4	550	7.5	*	17.0
	6/27/2001	Base	2.67	16.9	6.94	71.4	601	7.7	258	2.1
4	5/16/2001	Storm	10.50	18.3	6.4	68.6	330	7.3	*	290.0
	6/27/2001	Base	0.11	18.6	7.33	81.2	665	7.9	255	2.6
5	5/16/2001	Storm	20.11	16.1	6.9	70.1	710	7.4	*	21.0
	6/27/2001	Base	30.33	18.9	10.59	115.5	693	8.0	262	9.8
6	5/16/2001	Storm	33.88	14.9	7	69.3	640	7.6	*	17.0
	6/27/2001	Base	29.90	18.6	10.6	115.0	690	8.0	268	6.8
7	5/16/2001	Storm	15.79	14.6	6.55	64.4	1950	7.7	*	13.0
	6/27/2001	Base	14.90	19.1	8.1	88.5	680	7.8	261	12.0
8	5/16/2001	Storm	17.56	15.4	6.5	65	630	7.6	*	4.8
	6/27/2001	Base	6.71	20.2	7.7	85.0	688	7.9	251	5.1
9	6/6/2001	Storm	13.88	11	8	72.5	500	7.6	*	10.8
	6/27/2001	Base	1.55	15.9	5.3	54.0	620	7.7	262	1.3

* = Alkalinity was only sampled during the base flow event.

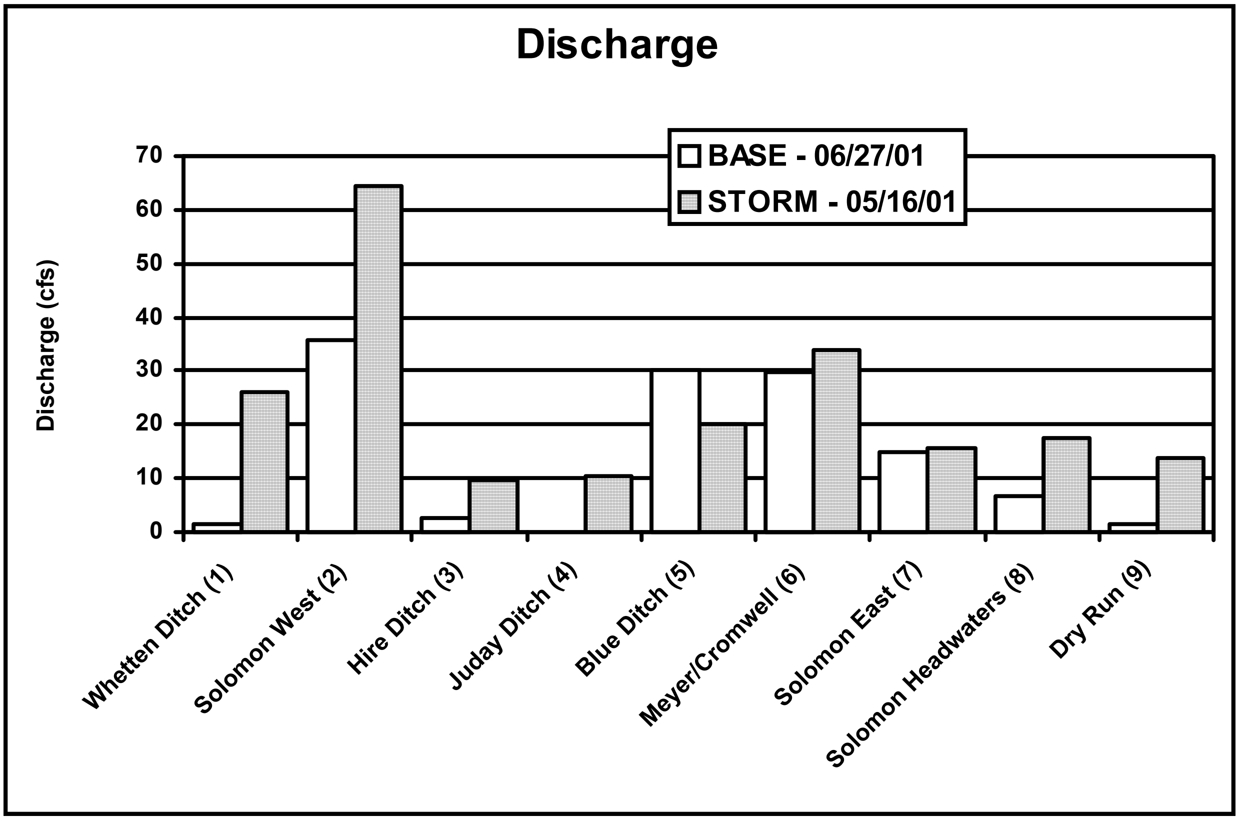

FIGURE 42. Discharge or flow measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

During base flow conditions, temperatures in the creeks varied from 15°C (59°F) in Whetten Ditch (Site 1) to 20.2°C (68.4°F) in Solomon Creek (Site 8). Water temperatures during storm flow varied from 11°C (51.8°F) in Dry Run (Site 9) to 18.3°C (64.9°F) in Juday Ditch (Site 4). All temperatures were within ranges suitable for aquatic life. Those creeks with cooler temperatures likely had a greater proportion of groundwater flowing in them. Streamside vegetation that provides shading to the water can also prevent heat gain. The higher base flow temperatures in streams located higher in the watershed (Sites 7 and 8) were likely due to their small size, lack of riparian shading, and lower proportion of groundwater inputs. Additionally, point sources like the Maple Leaf Farms Hatchery also contribute thermal pollution to the stream.

Dissolved oxygen (DO) concentrations varied from 5.3 mg/l to 10.6 mg/l. Because DO varies with temperature (cold water can contain more oxygen than warm water), it is relevant to consider DO saturation values. This refers to the amount of oxygen dissolved in water compared to the maximum possible when water is in equilibrium with the atmosphere and is saturated with oxygen. The 100% saturation value of water at 18°C is 9.5 mg/l. Stream dissolved oxygen concentrations that are less than 100% saturated suggest that: a) decomposition processes within the stream consume oxygen more quickly than it can be replaced by diffusion from the atmosphere, and b) flow in the streams is not turbulent enough to entrain sufficient oxygen. Stream data indicate that saturated dissolved oxygen conditions occurred only in Blue Ditch (Site

5) and Solomon Creek (Site 6) during base flow. DO averaged 78% across the remaining sites with Dry Run (Site 9) measuring a low 54% saturation. Under-saturated water in streams means that significant respiration, likely caused by bacteria decomposing dissolved and particulate organic matter, is consuming oxygen faster than the flowing water can replace it by turbulent mixing. DO in all streams exceeded the Indiana state minimum standard of 6 mg/l indicating that oxygen was sufficient to support aquatic life.

Conductivity in Dry Run, Solomon Creek, and Whetten Ditch Watershed streams ranged from 320 µmhos to 1950 µmhos during storm water runoff and from 505 µmhos to 693 µmhos during base flow. Conductivity during low discharge was generally higher than conductivity during storm sampling. High flows tend to dilute charge-bearing ions and allow little time for ion dissolution into the water from the soils.

Values of pH were well within the range of 6-9 units established by the Indiana Administrative Code. pH levels during base flow were generally greater (7.7-8.0) than levels measured during storm flow conditions (7.2-7.7). During low water periods, stream water has more time to accrue buffering compounds from alkaline soils. Alkalinity measurements taken during base flow conditions indicate that streams in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds are well-buffered.

During periods of high flow, turbidity was typically greater due to increased overland flow carrying suspended sediments with it into the creeks. Whetten Ditch and Juday Ditch (Sites 1 and 4) became notably more turbid during runoff. Turbidity was greatest during storm flow conditions for all sites except Solomon Creek at Site 8, which measured 4.8 NTU during storm runoff and 5.1 NTU during base flow conditions. During base flow conditions, Dry Run (Site 9) had the lowest turbidity of 1.3 NTU while Solomon Creek at Site 7 had the greatest turbidity of 12.0 NTU.

Chemical and Bacterial Parameter Concentrations
Chemical and bacterial concentration data for Whetten Ditch, Solomon Creek, and Dry Run, Watershed streams are listed by site in Table 46. Figures 43-50 present concentration information graphically.

TABLE 46. Chemical and bacterial data collected during stream chemistry sampling events in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds on 5/16/2001 and 6/27/2001.

Site	Date	Timing	NO_3^- (mg/l)	NH_3 (mg/l)	TKN (mg/l)	SRP (mg/l)	TP (mg/l)	TSS (mg/l)	*E. coli* (col/100ml)
1	5/16/2001	Storm	7.000	0.250	1.800	0.060	0.430	91	1900
1	6/27/2001	Base	3.388	0.049	0.345	0.012	0.029	2.1	400
2	5/16/2001	Storm	5.800	0.090	0.860	<0.05	0.150	35	900
2	6/27/2001	Base	1.396	0.018*	0.393	0.002	0.034	5.6	200
3	5/16/2001	Storm	6.900	<0.05	0.260	<0.05	0.120	10	900
3	6/27/2001	Base	3.068	0.018*	0.335	0.006	0.032	0.4	<100
4	5/16/2001	Storm	5.900	0.770	2.900	0.060	0.510	75	5700
4	6/27/2001	Base	7.693	0.021	0.533	0.079	0.104	2.3	200
5	5/16/2001	Storm	6.500	0.160	0.360	<0.05	0.140	21	230
5	6/27/2001	Base	3.013	0.018*	0.626	0.006	0.068	25.8	100
6	5/16/2001	Storm	5.000	<0.05	0.580	<0.05	0.170	11	460
6	6/27/2001	Base	1.292	0.018*	0.427	0.009	0.039	8.3	200
7	5/16/2001	Storm	1.900	0.150	0.710	<0.05	0.140	28	180
7	6/27/2001	Base	0.952	0.041	0.524	0.009	0.065	17.5	100
8	5/16/2001	Storm	1.300	<0.05	0.870	<0.05	0.120	3	154
8	6/27/2001	Base	1.015	0.018	0.625	0.009	0.049	5.7	<100
9	6/6/2001	Storm	18.000	<0.05	<0.1	0.120	0.120	1	790
9	6/27/2001	Base	8.117	0.018*	13.089	0.018	0.029	0.1	700

* Method Detection Limit

Nitrate-nitrogen concentrations in the Whetten Ditch, Solomon Creek, and Dry Run Watershed streams are illustrated in Figure 43. Nitrate-nitrogen concentrations at every site except Solomon Creek at Site 8 exceeded 1.6 mg/l, the median nitrate concentration of wadeable streams found by the Ohio EPA to support modified warmwater habitat (MWH) (Ohio EPA 1999). Other than Dry Run, no stream exceeded the IAC standard of 10 mg/l. Juday Ditch (Site 4) was the only site to measure higher nitrate concentrations during base flow than during storm runoff.

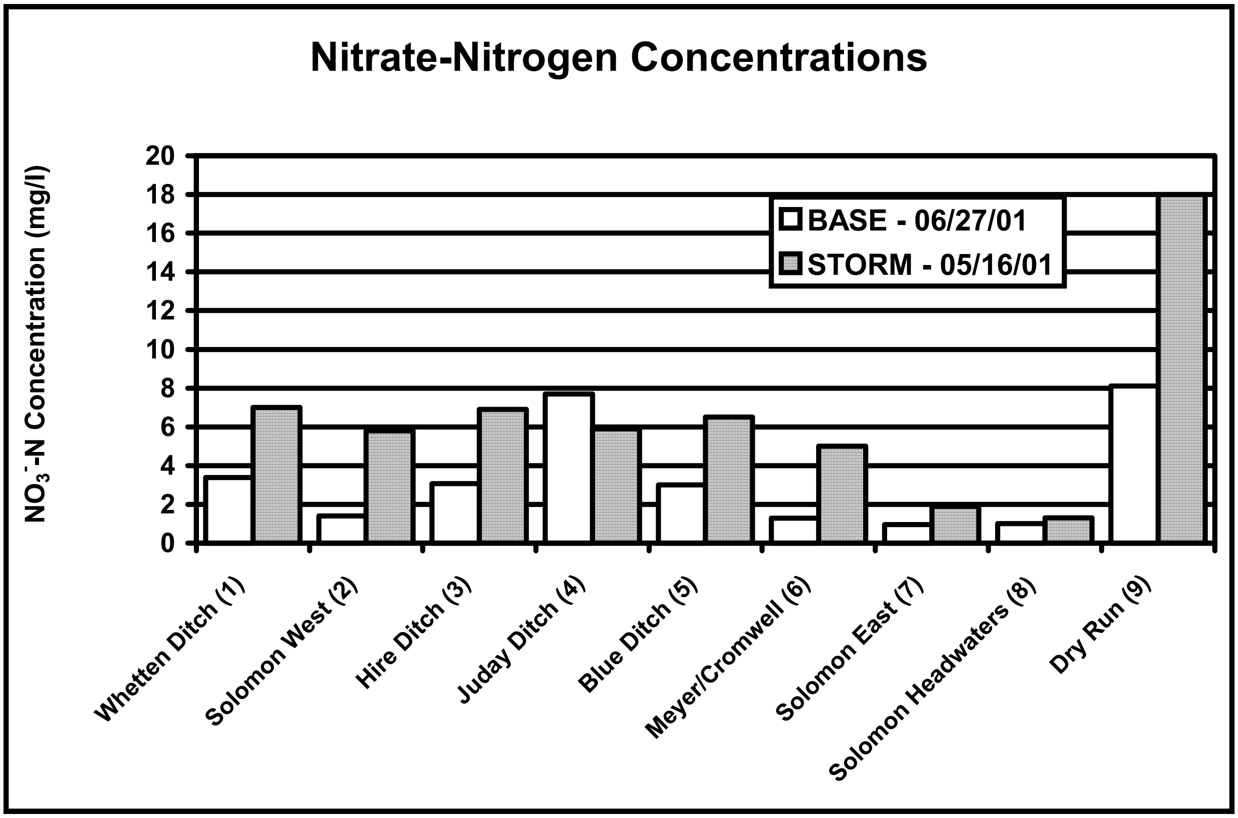

FIGURE 43. Nitrate-nitrogen concentration measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

Ammonia-nitrogen concentrations (Figure 44) generally fell within or below the range (0.13-0.22 mg/l) set by the IAC for the protection of aquatic life. (The standard is a range because the toxicity of ammonia depends both on temperature and pH.) During storm flows, Juday Ditch (Site 4) and Whetten Ditch (Site 1) exceeded the top end of the range at 0.25 and 0.77 mg/l respectively. High rates of runoff during storms can wash ammonia from fields and livestock areas into streams.

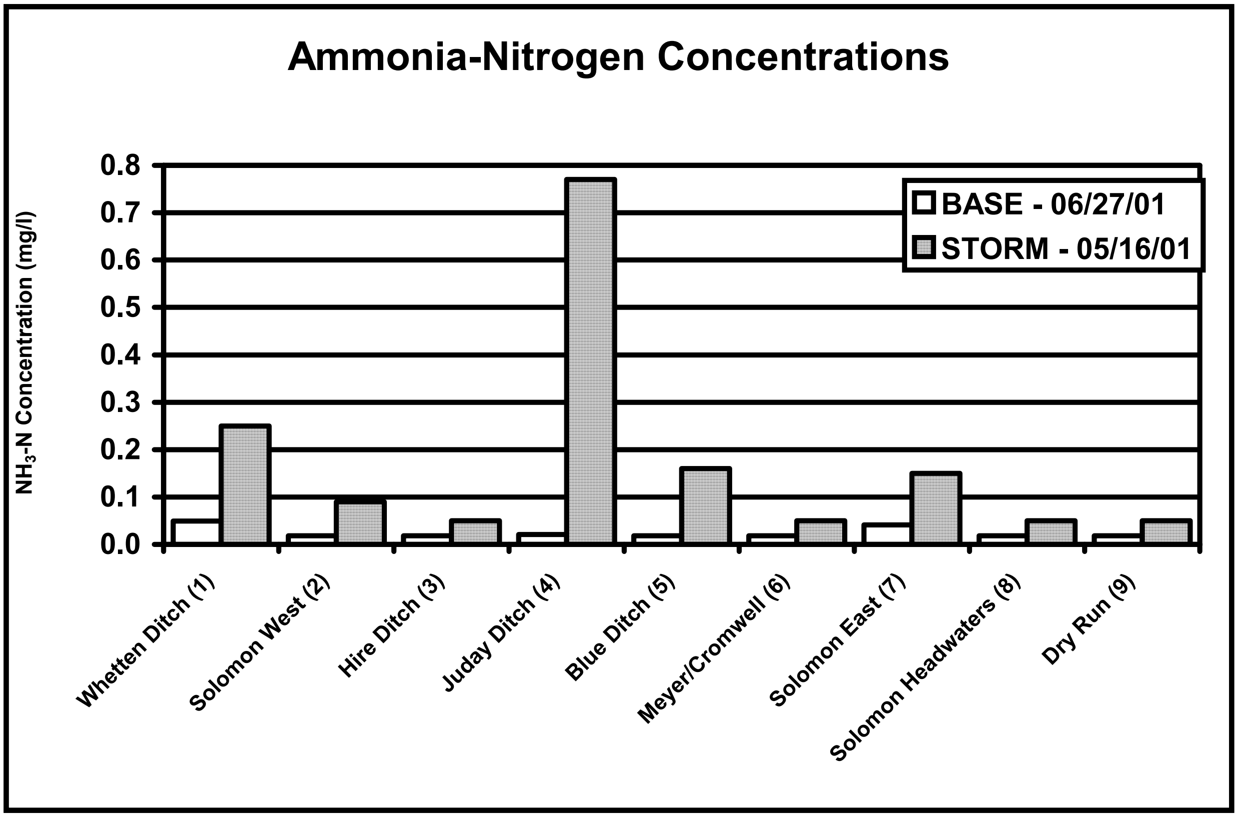

FIGURE 44. Ammonia-nitrogen concentration measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

Whetten Ditch (Site 1) and Juday Ditch (Site 4) exhibited elevated storm flow levels of TKN. Ammonia, which is included in the TKN measurement, was also elevated at these two sites (Figure 45), suggesting the possibility of an organic nitrogen source. The researchers collecting base flow samples did not notice anything unusual at Dry Run (Site 9) that would explain the greatly elevated base flow TKN concentration measured there (13.1 mg/l). A localized disturbance may have resulted in organic nitrogen entrainment into the water column.

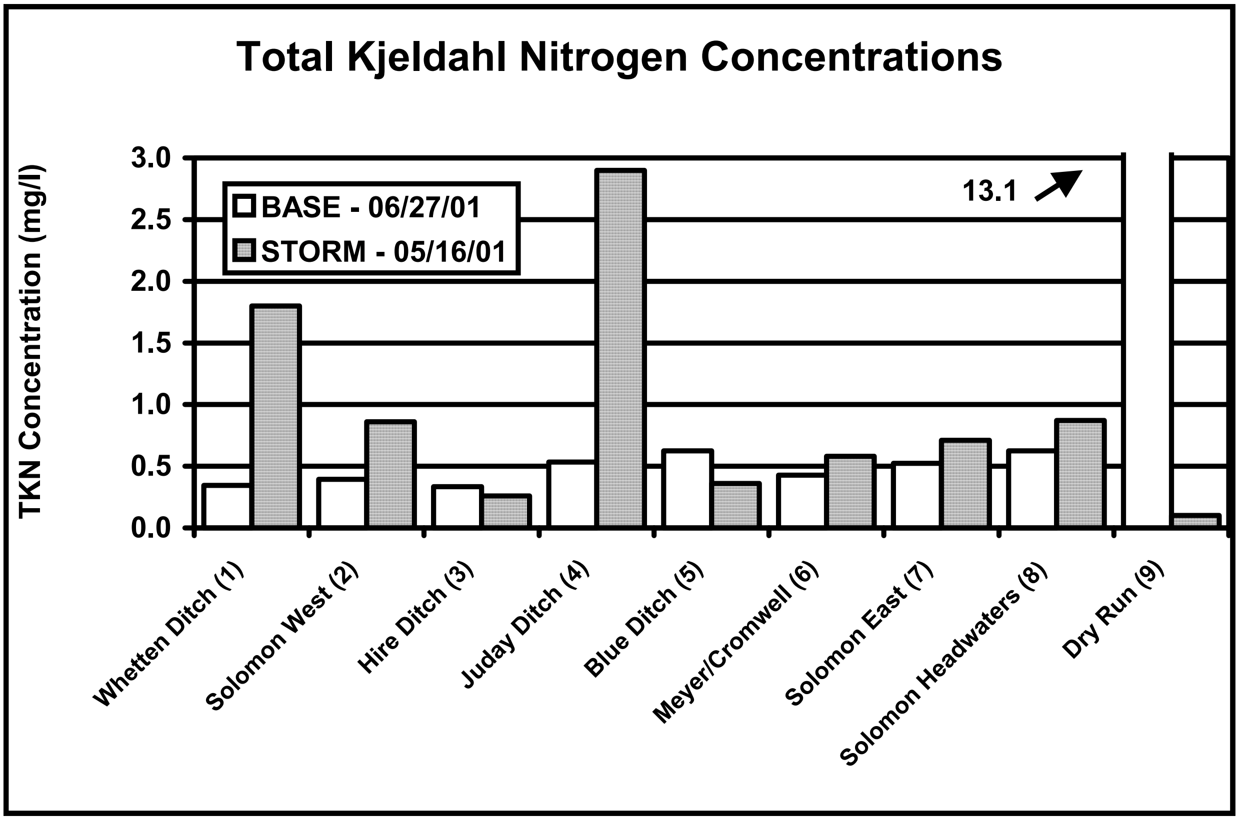

FIGURE 45. Total Kjeldahl nitrogen (TKN) concentration measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

All storm event concentrations of soluble reactive phosphorus (SRP) exceeded minimum levels that prevent overproductivity in aquatic systems (Figure 46). Storm flow concentrations in Dry Run (Site 9) and base flow concentrations in Juday Ditch (Site 4) were significantly elevated. Samples from most subwatersheds revealed that the soluble phosphorus fraction was <50% of the total phosphorus (TP) suggesting that most phosphorus loading was particulate or soil-associated (Figure 47). However, SRP was >60% of TP at Site 4 (Juday Ditch) and Site 9 (Dry Run). In fact during storm flow conditions in Dry Run, TP was 100% SRP.

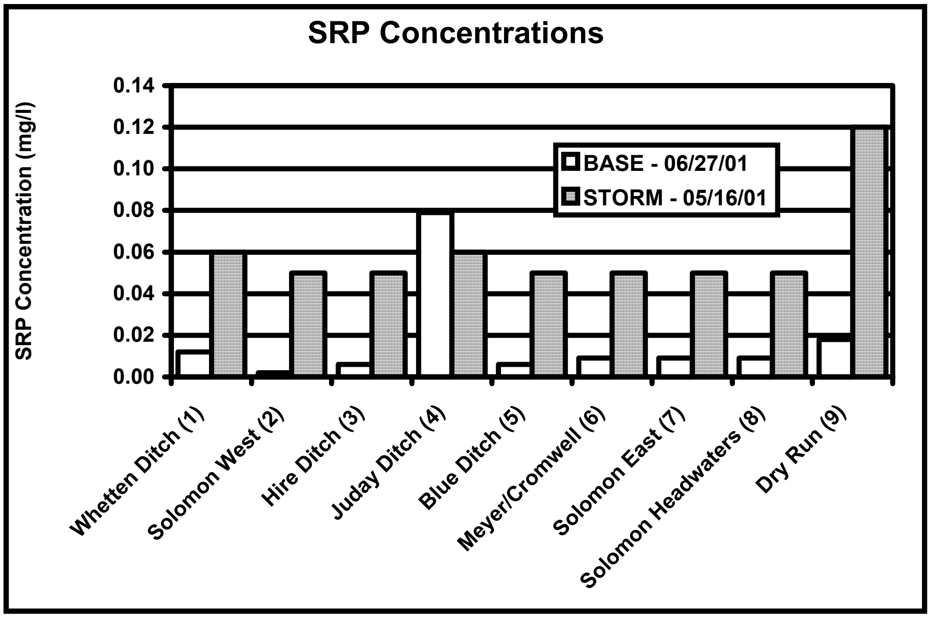

FIGURE 46. Soluble reactive phosphorus (SRP) concentration measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

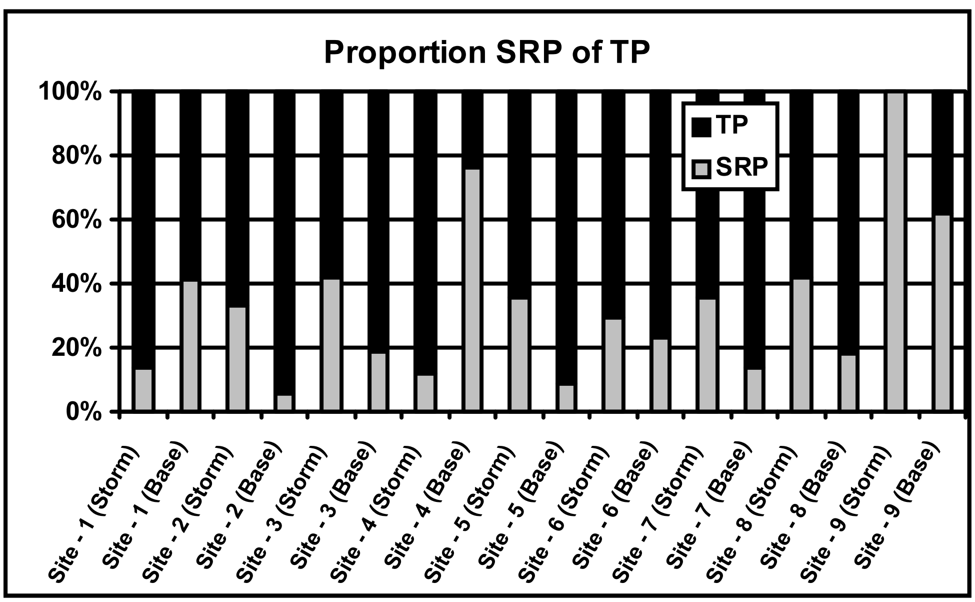

FIGURE 47. Soluble reactive phosphorus (SRP) percentage of total phosphorus (TP) concentration measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

Total phosphorus (TP) concentrations in stormwater runoff (Figure 48) were notably elevated, especially in Whetten Ditch (Site 1) and Juday Ditch (Site 4). TP levels in Juday Ditch were nearly 17 times the minimum level that causes eutrophication of temperate waterbodies (0.03 mg/l). Most sites also exceeded the eutrophication level during base flow, but all sites maintained TP concentrations below the 0.28 mg/l level acceptable for modified warmwater habitat (Ohio EPA, 1999).

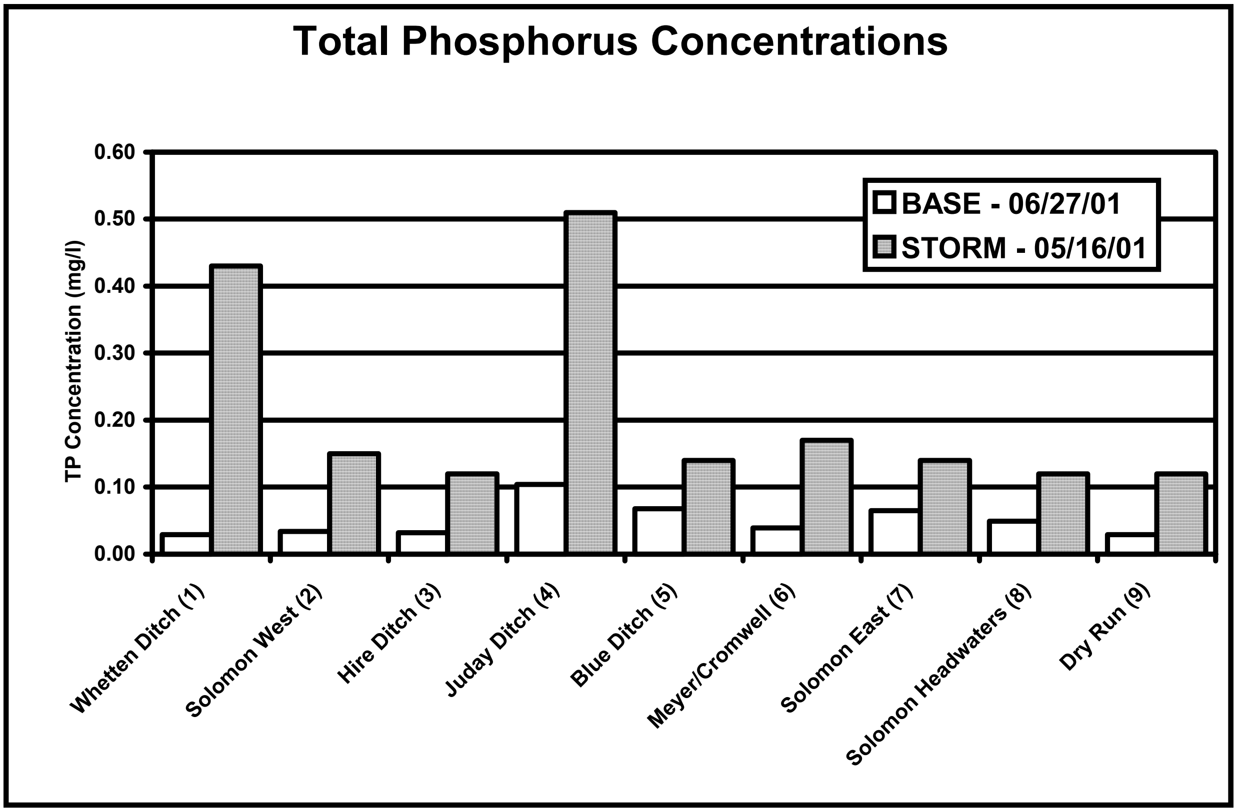

FIGURE 48. Total phosphorus (TP) concentration measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

In general, concentrations of total suspended solid (TSS) concentrations were greater during storm flow conditions than during the base flow event (Figure 49). The difference in base and storm TSS concentrations was particularly marked in Whetten and Juday Ditches (Site 1 and 4). Suspended solid concentrations in Whetten Ditch exceeded the 80-mg/l level known to be deleterious to aquatic life (Waters, 1995). The researchers who collected the base flow samples suspect that livestock with free access to Blue Ditch (Site 5) stirred up the sediments which resulted in the elevated TSS measurement.

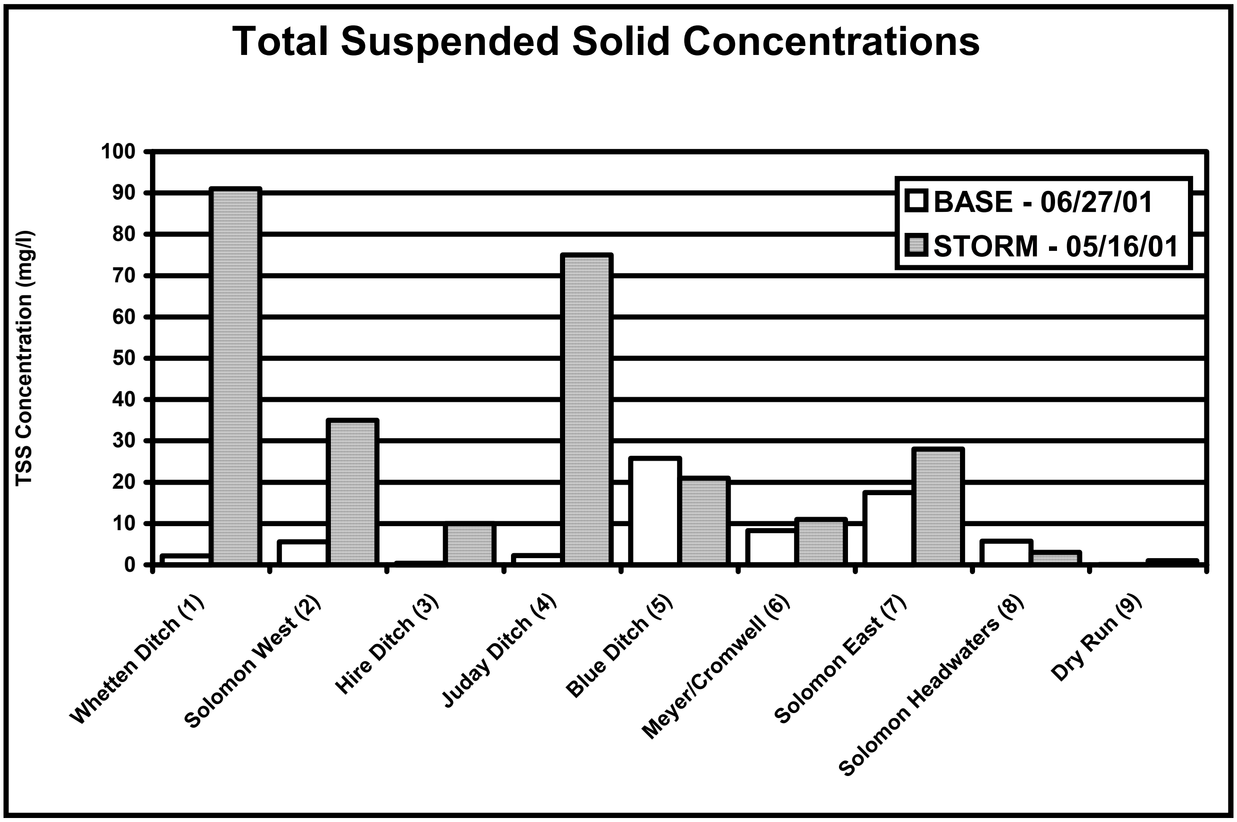

FIGURE 49. Total suspended solid (TSS) concentration measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

During the storm flow sampling, Blue Ditch (Site 5) and Solomon Creek at Sites 7 and 8 were the only sites that did not exceed Indiana state standards for *E. coli* (235 col/100ml; Figure 50). Storm flow concentrations in violation of the standard ranged from 460 to 5,700 col/100ml. As with many of the nutrient parameters measured during storm flow, Juday Ditch dominated *E. coli* loading as well. Base flow *E. coli* concentrations ranged from 154 col/100ml in Solomon Creek at Site 8 to 700 col/100ml in Dry Run (Site 9). Whetten Ditch (Site 1) and Dry Run (Site 4) were the only streams in violation of bacteriological standards during base flow.

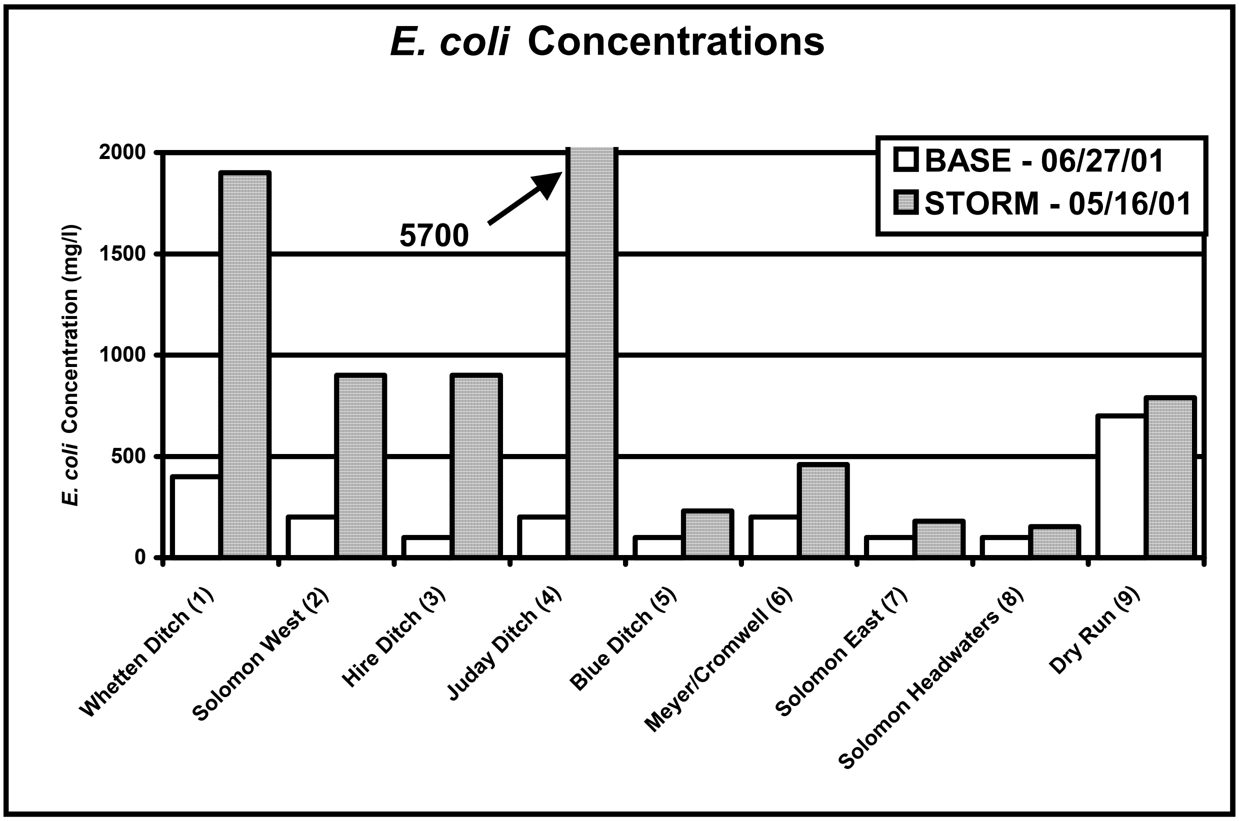

FIGURE 50. *E. coli* concentration measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

Chemical and Sediment Parameter Mass Loading

Nutrient and sediment loading from streams in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds was mostly governed by flow rate (i.e., streams with higher rates of flow also contributed higher nutrient and sediment loads). Table 47 summarizes sampling locations that loaded disproportionate amounts of the various parameters relative to discharge rate (i.e., these streams loaded more nutrients and/or sediment despite having smaller discharges than other streams where data was collected). Nitrate-nitrogen loading was governed by flow rate at all sites except Blue Ditch (Site 5) and Dry Run (Site 9) which each contributed more nitrate-nitrogen relative to discharge (Figure 51). Whetten Ditch (Site 1), Juday Ditch (Site 4), Blue Ditch (Site 5), and Solomon Creek (Site 7) contributed significantly to ammonia loading despite having relatively small flows (Figure 52). During the storm event Juday Ditch (Site 4) contributed disproportionately higher TKN loads relative to its flow rate (Figure 53). This was also the case for base flow Dry Run (Site 9) TKN contributions. Except for Dry Run (Site 9) during the storm event when SRP loading was disproportionate relative to flow, SRP loading was also governed by rate of flow (Figure 54). TP loading (Figure 55) was also disproportionately high in Whetten and Juday Ditches (Sites 1 and 4) during storm runoff and in Blue Ditch (Site 5) during base flow conditions. Whetten Ditch (Site 1), Juday Ditch (Site 4), Blue Ditch (Site 5), and Solomon Creek (Site 7) carried larger amounts of suspended solids relative to rate of discharge, suggesting that these subwatershed areas had detectibly higher sediment loss rates (Figure 56). Sediment loading rates were variable but quite high at some sites ranging from <1 to 5,845 kg/day (<1 to 12,888 lbs/day) depending on flow regime and location.

TABLE 47. Streams that loaded disproportionate amounts of the various parameters relative to discharge rate.

Site	Parameter	Event
Whetten Ditch (Site 1)	NH_3-N	Storm
Whetten Ditch (Site 1)	TP	Storm
Whetten Ditch (Site 1)	TSS	Storm
Juday Ditch (Site 4)	NH_3-N	Storm
Juday Ditch (Site 4)	TKN	Storm
Juday Ditch (Site 4)	TP	Storm
Juday Ditch (Site 4)	TSS	Storm
Blue Ditch (Site 5)	NO_3^--N	Base
Blue Ditch (Site 5)	NH_3-N	Storm
Blue Ditch (Site 5)	TP	Base
Blue Ditch (Site 5)	TSS	Base and Storm
Solomon Creek (Site 7)	NH_3-N	Base and Storm
Solomon Creek (Site 7)	TKN	Base and Storm
Solomon Creek (Site 7)	TSS	Storm
Dry Run (Site 9)	NO_3^--N	Base and Storm
Dry Run (Site 9)	TKN	Base
Dry Run (Site 9)	SRP	Storm

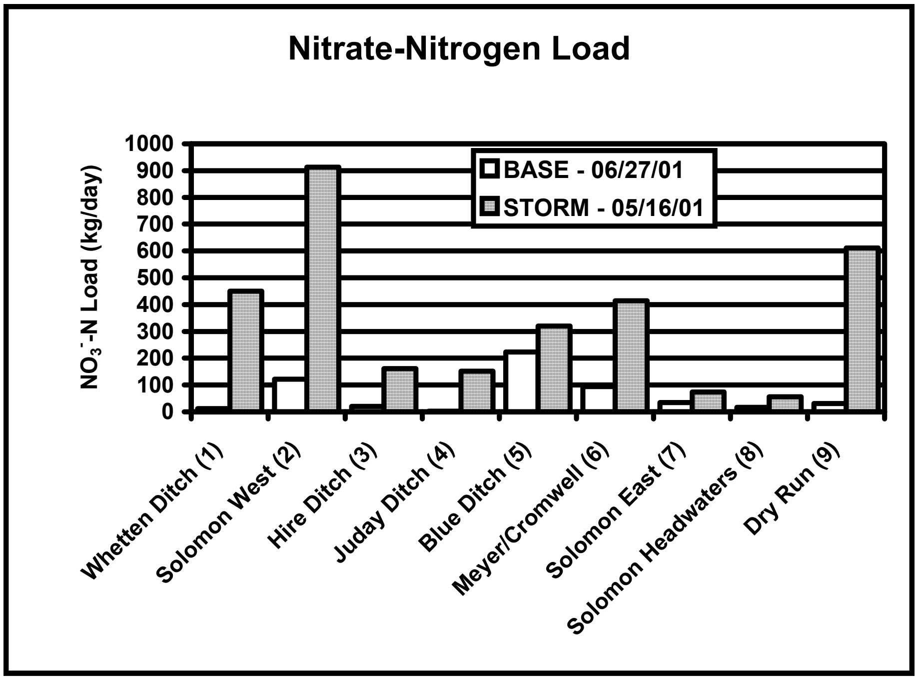

FIGURE 51. Nitrate-nitrogen loading measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

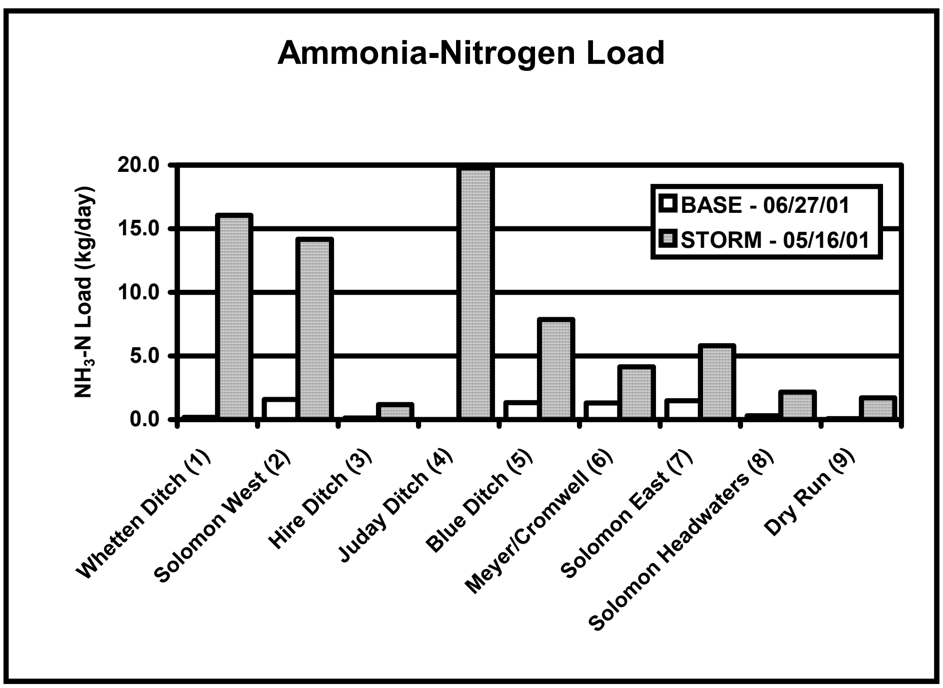

FIGURE 52. Ammonia-nitrogen loading measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

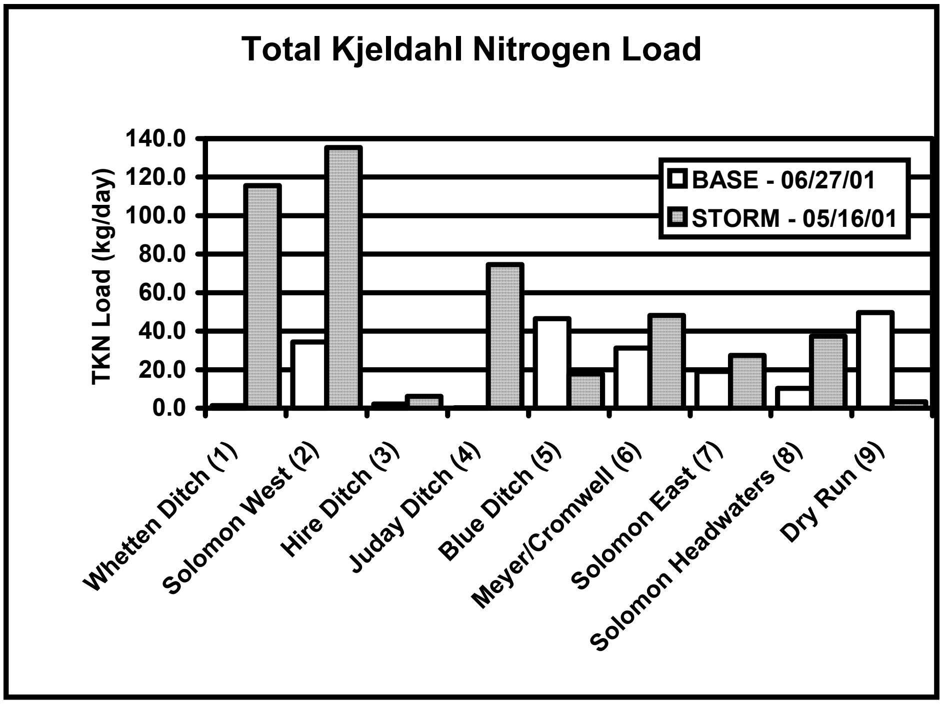

FIGURE 53. Total Kjeldahl nitrogen (TKN) loading measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

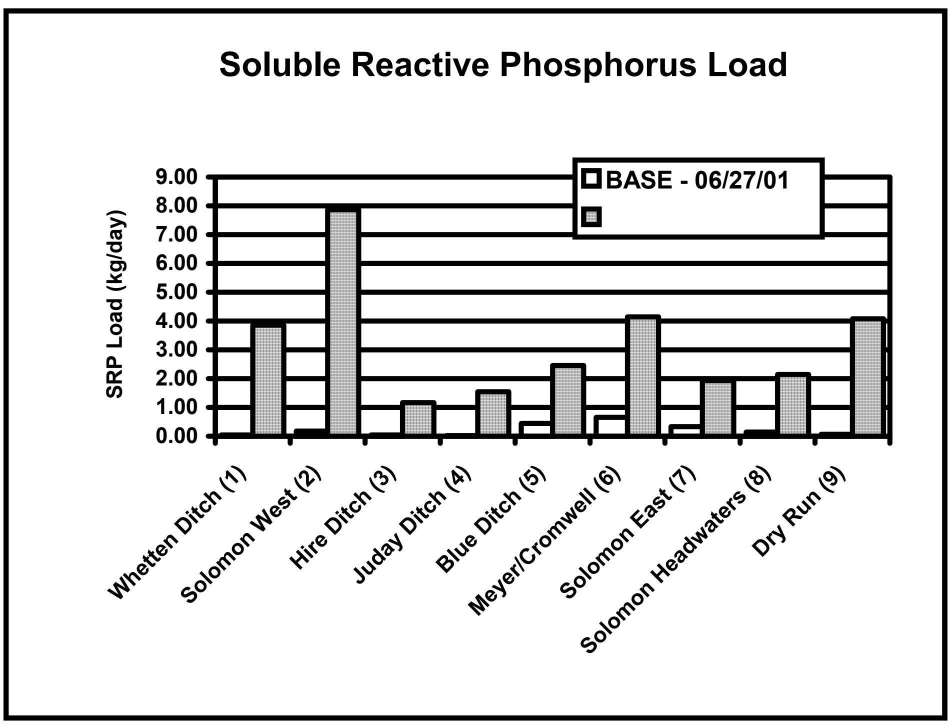

FIGURE 54. Soluble reactive phosphorus (SRP) loading measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

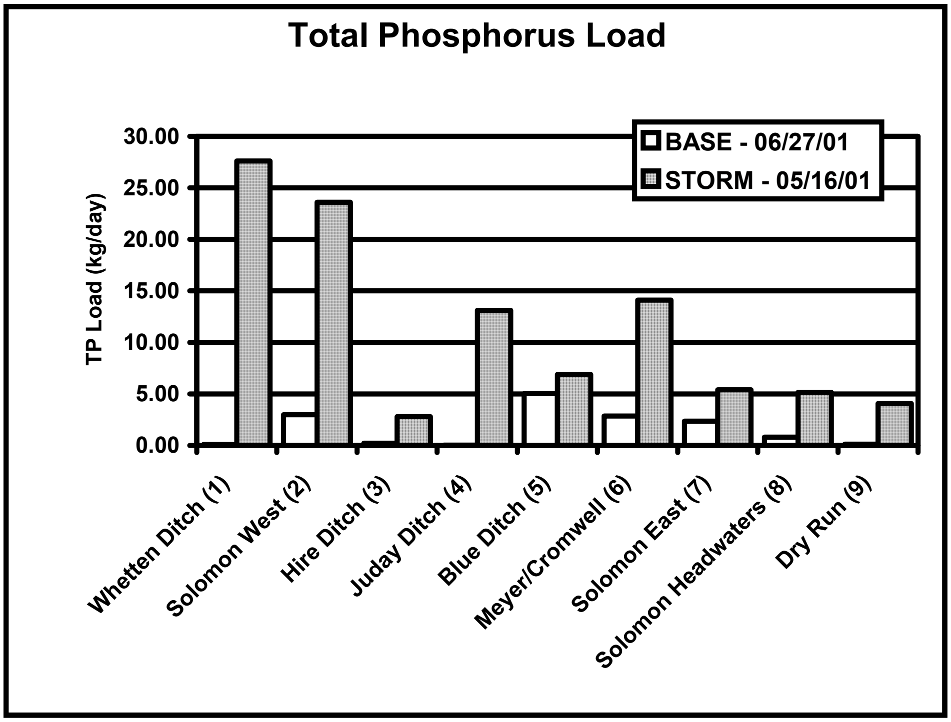

FIGURE 55. Total phosphorus (TP) loading measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

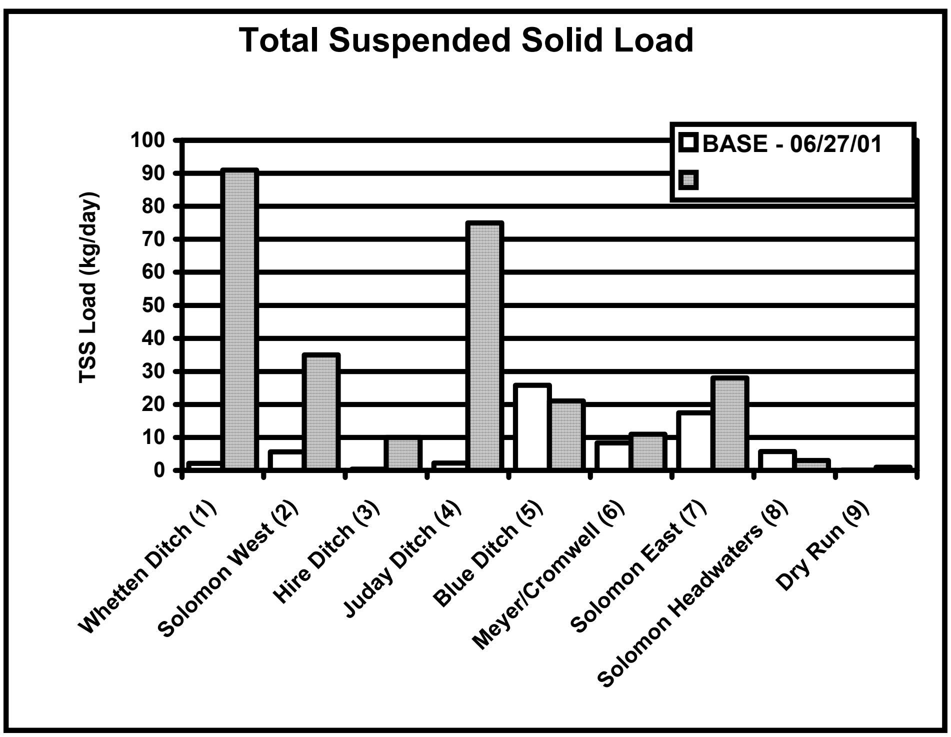

FIGURE 56. Total suspended solid (TSS) loading measurements during base flow and storm flow sampling of Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

Water Chemistry Discussion

In an effort to normalize the sediment, nutrient, and bacteria loading rates, the rates were divided by subwatershed size above each sampling site. Sampling sites in certain subwatersheds received loading from adjacent subwatersheds. In these cases, loads from adjacent subwatersheds were subtracted from the subwatershed of consideration. Table 48 shows sample sites representing the respective subwatersheds. Due to limited resources for sampling, per-unit-area loading by the Mouths Solomon Creek and Dry Run Subwatershed (10) could not be characterized. Table 49 shows the results of this analysis.

TABLE 48. Sampling sites representing subwatersheds within the study area.

Watershed/Subwatershed	Sampling Site(s)
Whetten Ditch Subwatershed	1
Solomon Creek West Subwatershed	= 2-3-4
Hire Ditch Subwatershed	3
Juday Ditch Subwatershed	4
Blue Ditch Subwatershed	5
Meyer/Cromwell Ditch Subwatershed	6
Solomon Creek East Subwatershed	= 7-8
Solomon Creek Headwaters Subwatershed	8
Dry Run Subwatershed	9

TABLE 49. Areal loading of TSS, TP, and *E. coli* by subwatershed based on the base flow and storm flow sampling events.

Watershed/Subwatershed	Watershed Size	Timing	TSS Load (kg/ha/yr)	TP Load (kg/ha/yr)	*E. coli* Load (billions of col/ha/yr)
Whetten Ditch Subwatershed	3528 ac (1428 ha)	base	2.0	0.03	3.75
Whetten Ditch Subwatershed	3528 ac (1428 ha)	storm	1494.0	7.06	311.93
Solomon Creek West Subwatershed	3311 ac (1340 ha)	base	131.68	0.71	44.81
Solomon Creek West Subwatershed	3311 ac (1340 ha)	storm	-465.04	-7.35	-1119.10
Hire Ditch Subwatershed	2644 ac (1070 ha)	base	0.9	0.07	2.23
Hire Ditch Subwatershed	2644 ac (1070 ha)	storm	79.9	0.96	71.9
Juday Ditch Subwatershed	922 ac (373 ha)	base	0.6	0.03	0.53
Juday Ditch Subwatershed	922 ac (373 ha)	storm	1885.6	12.82	1433.03
Blue Ditch Subwatershed	1251 ac (506 ha)	base	1381.2	3.64	53.53
Blue Ditch Subwatershed	1251 ac (506 ha)	storm	745.4	4.97	81.64
Meyer/Cromwell Ditch Subwatershed	5119 ac (2072 ha)	base	107.1	0.50	25.78
Meyer/Cromwell Ditch Subwatershed	5119 ac (2072 ha)	storm	160.6	2.48	67.18
Solomon Creek East Subwatershed	4721 ac (1911 ha)	base	112.69	0.37	5.36
Solomon Creek East Subwatershed	4721 ac (1911 ha)	storm	194.07	0.53	6.84
Solomon Creek Headwaters Subwatershed	9256 ac (3747 ha)	base	9.2	0.08	1.60
Solomon Creek Headwaters Subwatershed	9256 ac (3747 ha)	storm	12.6	0.50	6.45
Dry Run Subwatershed	2760 ac (1117 ha)	base	0.1	0.04	8.68
Dry Run Subwatershed	2760 ac (1117 ha)	storm	11.1	1.33	87.67

The Juday Ditch Subwatershed contributed more sediment per unit area than any other subwatershed during storm water runoff. The Whetten Ditch, Juday Ditch, Blue Ditch, Meyer/Cromwell Ditch, and Solomon Creek East Subwatersheds each loaded over 100 kg/ha/yr (221 lbs/ac/yr) during storm flows. Sediment loading was lower during low flow conditions for most subwatersheds; however, sediment loading was actually greater during baseline conditions than during storm runoff for the Solomon Creek West and the Blue Ditch Subwatersheds. Less suspended solids were measured leaving the Solomon Creek West Subwatershed indicating that it served as a depositional area for sediment during at least some portion of the hydrologic cycle. Per acre of subwatershed area, Juday Ditch contributed the greatest load of total phosphorus. Again the Solomon Creek West Subwatershed was a depositional area or net sink area for total phosphorus having negative areal loading rates during storms. *E. coli* loading was worst from the Juday Ditch Subwatershed which loaded as much as 1433 billion col/ha/yr during base flow conditions. Areal bacterial loading was also elevated in the Whetten Ditch, Dry Run, and Blue Ditch Subwatersheds. On the other hand, Solomon Creek West was a net sink of *E. coli* bacteria during storm flows. This net loss is probably due to death or deposition without substantial bacterial input within this reach.

Water Chemistry Summary

In general, physical and chemical parameter data collected from streams in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds indicate moderate to severe degradation when compared with ideal conditions. Nutrient concentrations were generally higher than median nutrient concentrations observed in modified Ohio streams known to support healthy modified warmwater habitats for aquatic life. Although storm flow runoff conditions induced nutrient and bacteria concentrations that violated Indiana state standards for both human and aquatic biota health, most samples collected during base flow fell within state acceptable ranges. Sediment loading rates were variable but quite high at some sites ranging from <1 to 5,845 kg/day (<1 to 12,888 lbs/day) depending on flow regime and location. While some reaches per unit area acted as net sinks for sediment, phosphorus, and bacteria, some delivered significant loads of sediment, nutrients, and bacteria particularly during high water stage. The Juday Ditch Subwatershed contributed more sediment, phosphorus, and *E. coli* than any other subwatershed during storm conditions per unit area (Table 49). In conclusion according to the stream chemistry data, creeks where water quality could be considered impaired include Juday Ditch, Blue Ditch, Solomon Creek East, Dry Run, and Whetten Ditch.

<u>Macroinvertebrates and Habitat</u>

Macroinvertebrate Sampling Methods

Macroinvertebrate samples from each of the 9 sites and the reference site were used to calculate an index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The insect community composition reflects water quality, and research shows that different macroinvertebrate orders and families react differently to pollution sources. Indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995).

Macroinvertebrates were collected during base flow conditions on May 30 and 31, 2000 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al., 1999). This method was supplemented by qualitative picks from substrate and by surface netting. Two researchers collected macroinvertebrates for 20 minutes, and a third researcher aided in the collection for 10 minutes for a total of 50 minutes of collection effort. The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the same manual. Organisms were identified to the family level. The family-level approach was used: 1) to collect data comparable to that collected by IDEM in the state; 2) because it allows for increased organism identification accuracy; 3) because several studies support the adequacy of family-level analysis (Furse et al., 1984; Ferraro and Cole, 1995; Marchant, 1995; Bowman and Bailey, 1997; Waite et al., 2000).

Macroinvertebrate data were used to calculate the family-level Hilsenhoff Biotic Index (HBI). Calculation of the HBI involves applying assigned macroinvertebrate family tolerance values to all taxa present that have an assigned HBI tolerance value, multiplying the number of organisms present by their family tolerance value, summing the products, and dividing by the total number of organisms present (Hilsenhoff, 1988). A higher value on the HBI scale indicates greater impairment.

In addition to the HBI, macroinvertebrate results were analyzed by applying an adaptation of the IDEM mIBI (IDEM, 1996). mIBI scores allow comparison with data compiled by IDEM for wadeable riffle-pool streams. IDEM developed the classification criteria based on five years of wadeable riffle-pool data collected from throughout Indiana. The data were lognormally distributed for each of the metrics. Each metric's lognormal distribution was then pentasected with scoring based on five categories using 1.5 times the interquartile range around the geometric mean. Table 50 lists the eight scoring metrics used in this study with classification scores of 0-8. The mean of the eight metrics is the mIBI score. mIBI scores of 0-2 indicate the sampling site is severely impaired, scores of 2-4 indicate the site is moderately impaired, scores of 4-6 indicate the site is slightly impaired, and scores of 6-8 indicate that the site is non-impaired.

TABLE 50. Benthic macroinvertebrate scoring metrics and classification scores used by IDEM in evaluation of riffle-pool streams in Indiana.

	SCORING CRITERIA FOR THE FAMILY LEVEL MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (mIBI) USING PENTASECTION AND CENTRAL TENDENCY ON THE LOGARITHMIC TRANSFORMED DATA DISTRIBUTIONS OF THE 1990-1995 RIFFLE KICK SAMPLES				
		CLASSIFICATION SCORE			
	0	2	4	6	8
Family Level HBI	≥5.63	5.62- 5.06	5.05-4.55	4.54-4.09	≤4.08
Number of Taxa	≤7	8-10	11-14	15-17	≥18
Percent Dominant Taxa	≤61.6	61.5-43.9	43.8-31.2	31.1-22.2	≥ 22.1
EPT Index	≤2	3	4-5	6-7	≥8
EPT Count	≤19	20-42	43-91	92-194	≥195
EPT Count To Total Number of Individuals	≤0.13	0.14-0.29	0.30-0.46	0.47-0.68	≥0.69
EPT Count To Chironomid Count	≤0.88	0.89-2.55	2.56-5.70	5.71-11.65	≥11.66
Chironomid Count	≤147	146-55	54-20	19-7	≥6

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Nonimpaired

Habitat Sampling Methods

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the metrics used to determine the QHEI score which generally ranges from 20 to 100. An example of the QHEI data sheet is given in Appendix 7.

Substrate type(s) and quality are important factors of habitat quality and the QHEI score is partially based on these characteristics. Sites that have greater substrate diversity receive higher scores as they can provide greater habitat diversity for benthic organisms. The quality of substrate refers to the embeddedness of the benthic zone. Small particles of soil and organic matter will settle into small pores and crevices in the stream bottom. Many organisms can colonize these microhabitats, but high levels of silt in a streambed can result in the loss of habitat within the substrate, thus sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

In-stream cover, another metric of the QHEI, represents the type(s) and quantity of habitat provided within the stream itself. Examples of in-stream cover include woody logs and debris, aquatic and overhanging vegetation, and root wads extending from the stream banks. The channel morphology metric evaluates the stream's physical development with respect to habitat diversity. Pool and riffle development within the stream reach, the channel sinuosity, and other factors that represent the stability and direct modification of the site are evaluated to comprise this metric score.

A wooded riparian buffer is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal, and assimilation of nutrients. According to the Ohio EPA (1999), riparian zones govern the quality of goods and services provided by riverine ecosystems. Riparian zone and bank erosion were examined at each site to evaluate the quality of the buffer zone of the stream, the land use within the floodplain that affects inputs to the waterway, and the extent of bank erosion, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian buffer is a zone that is forest, shrub, swamp, or woody old-field vegetation. Typically, weedy, herbaceous vegetation does not offer as much infiltration potential as woody components and does not represent an acceptable riparian zone type for the QHEI (Ohio EPA, 1989).

The fifth metric of the QHEI evaluates the quality of pool-glide and riffle-run habitats in the stream. When present in a stream, these zones provide diverse habitat and in turn can increase habitat quality. The depth of pools within a reach and the stability of riffle substrate are some factors that affect the metric and QHEI score.

The final QHEI metric evaluates the topographic gradient in a stream reach. This is calculated using topographic data. The score for this metric is based on the premise that both very low and very high elevation gradients have negative effects on habitat quality. The gradient ranges for scoring take into account the fact that gradient has a varying influence depending on stream size. Moderate gradients receive a high score of 10 for this metric.

The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1995).

Macroinvertebrate and Habitat Results

mIBI and QHEI scores for each sampling site and the reference site are given in Tables 51 and 52. Detailed mIBI results are included in Appendix 8. The mIBI scores ranged from 0.75 to 6.00. All QHEI scores fell below 60, the level conducive to existence of warmwater faunas (Ohio EPA, 1999). Figure 57 shows cross-sections at each of the stream sampling sites. Nearly all of the sites have relatively steep banks, indicative of stream modification and channelization. Following the tables is a site-by-site description of particular characteristics that contributed to the evaluation results.

TABLE 51. Classification scores and mIBI score for sampling sites within the Whetten Ditch, Solomon Creek, and Dry Run Watersheds as sampled July 11-12, 2001.

	Whetten (1)	Solomon West (2)	Hire (3)	Juday (4)	Blue (5)	Meyer/ Cromwell (6)	Solomon East (7)	Solomon Head-waters (8)	Dry Run (9)
HBI	0	8	0	0	0	6	4	0	0
No. Taxa (family)	4	4	6	0	4	8	6	8	2
% Dominant Taxa	6	4	6	0	6	2	0	4	2
EPT Index	0	6	0	0	4	4	4	4	0
EPT Count	0	4	0	0	2	4	4	0	0
EPT Count/Total Count	0	6	0	0	4	8	4	0	0
EPT Abun./Chir. Abun.	0	8	0	0	2	6	4	2	0
Chironomid Count	4	8	6	8	6	6	6	8	2
mIBI Score	**1.75**	**6.00**	**2.25**	**1.00**	**3.50**	**5.50**	**4.00**	**3.25**	**0.75**

TABLE 52. QHEI Scores for the Whetten Ditch, Solomon Creek, and Dry Run Watershed sampling sites and reference site as sampled July 11-12, 2001.

Site	Substrate Score	Cover Score	Channel Score	Riparian Score	Pool Score	Riffle Score	Gradient Score	Total Score
Maximum Possible Score	20	20	20	10	12	8	10	**100**
SITE 1-Whetten Ditch	7.5	4	6	4	0	0	8	**29.5**
SITE 2-Solomon Creek	8.5	14	8	6	8	0	10	**54.5**
SITE 3-Hire Ditch	7.5	13	5	5	3	0	6	**39.5**
SITE 4-Juday Ditch	4	13	4	4	2	0	10	**37**
SITE 5-Blue Ditch	5.5	2	6	4	2	0	6	**25.5**
SITE 6-Solomon Creek	3.5	15	6	3.5	6	3	6	**43**
SITE 7-Solomon Creek	3.5	11	4	6	3	2	8	**37.5**
SITE 8-Solomon Creek	1	10	4	4.5	2	0	4	**25.5**
SITE 9- Dry Run	3.5	13	4	4	4	0	6	**34.5**

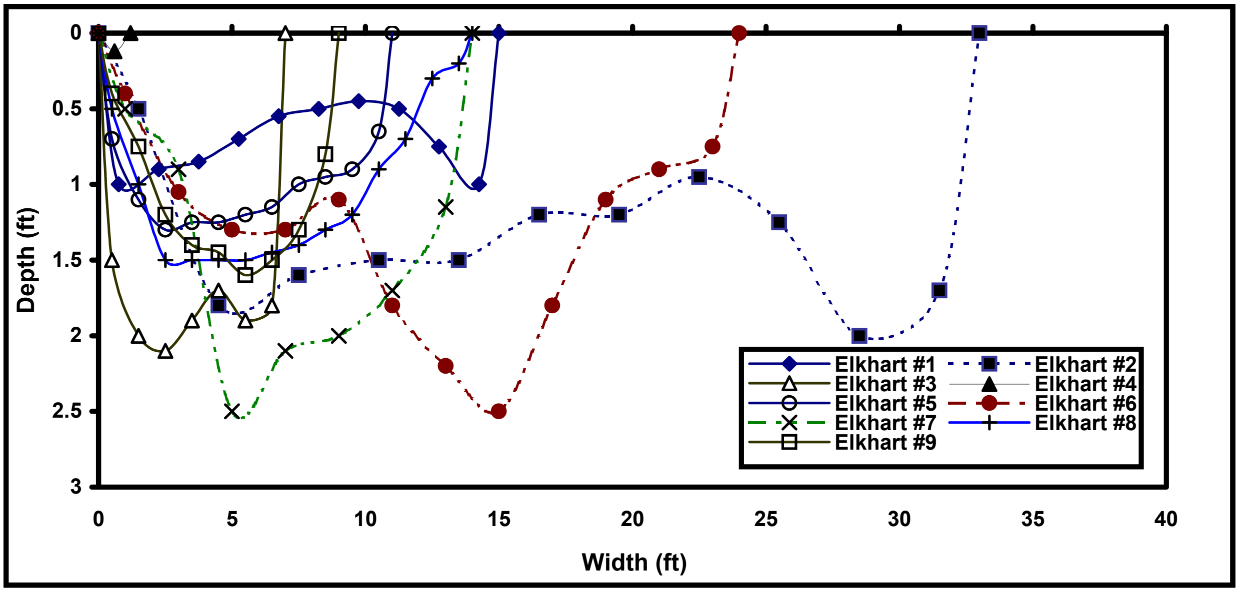

FIGURE 57. Cross-sections of streams at sampling locations.

Site 1 - Whetten Ditch. The QHEI score at this site was 29.5 of 100 total possible points. The poor score was attributed to the sparse levels of in-stream cover and poor channel morphology (Figure 58). The channel development was listed as poor and contributed to the lack of pool or riffle development at the site, limiting habitat diversity. The riparian zone buffering the site from the adjacent agricultural land use was very narrow. The substrate at the site was comprised of 80% sand and 20% gravel. Silt levels in the substrate were normal and embeddedness was low. The mIBI for the Whetten Ditch site was 1.75, an indication of "severe" impairment. The macroinvertebrate community was dominated by the dipteran family *Chironomidae,* a taxon of high tolerance.

FIGURE 58. Site 1 sampling location on Whetten Ditch.

Site 2 - Solomon Creek. This site received the highest QHEI score, 54.5 of a possible 100. The substrate was 65% sand and 30% gravel; cobble comprised most of the remaining percentage. Substrate embeddedness was low, but a moderate amount of silt and muck were present. The characteristic features of this site were in-stream cover and riparian zone quality (Figure 59).

The creek channel was buffered by a dense zone of young forest vegetation that provided both canopy and in-stream cover in the form of root wads, logs, and woody debris. The creek at this site was consistently deep and had the widest stream channel of any in the study area (33 feet; Figure 57). This contributed to the pool quality score, but no riffle development was observed at the site. The mIBI score at this site was also higher than any other study stream. This score of 6.0 indicated a "nonimpaired" system. The macroinvertebrate community was dominated by taxa that are considered relatively intolerant. The highly intolerant tricopteran *Brachycentridae* was the dominant taxon sampled at the site. This indicates that water and habitat quality were relatively unimpaired within this reach of Solomon Creek.

FIGURE 59. Site 2 sampling location on Solomon Creek.

Site 3 - Hire Ditch. Channelization and limited pool and riffle development characterized the habitat quality at this site. The channel lacked sinuosity and received a poor pool quality score. There was no riffle formation observed on site. The stream cross-section (Figure 57) showed that the stream was fairly deep (over 2 feet) for its relative width (7 feet). The riparian zone was comprised of tall grasses with little to no woody vegetation (Figure 60). The tall streamside grasses did provide shading. Some aquatic macrophyte growth within the stream channel provided moderate in-stream cover. The substrate was predominantly sand with gravel and fine particulate organic matter (FPOM) or "muck". The QHEI score of 39.5 reflects the relatively poor habitat quality of this site. The mIBI score of 2.25 is also an indicator of impaired conditions. Although a moderate diversity of organisms was collected, a lack of intolerant taxa characterized the macroinvertebrate community.

FIGURE 60. Site 3 sampling location on Hire Ditch.

Site 4 - Juday Ditch. Site 4 on Juday Ditch was entirely choked with grasses and aquatic macrophytes (Figure 61). The water was not visible through the vegetation. Even though canopy and in-stream cover were readily available, the QHEI score of 37 indicates that other habitat characteristics were of poor quality. The substrate was 50% sand, 25% silt, and 25% clay and received a score of 4 out of a possible 20 points. These types of fine, embedding substrates limit habitat quality for many macroinvertebrate communities. Juday Ditch lacked any resemblance to a natural waterway in that it was very straight and showed no recent recovery from channelization. From the cross-sections in Figure 57, it is apparent that the ditch was very narrow and shallow relative to the rest of the study sites. No woody riparian zones were present, and runoff from the surrounding agricultural fields was not impeded. The habitat was further limited by a homogenous channel with poor pool quality and no riffle development. The mIBI score of 1.0 was the second lowest score of the study and reflected the poor habitat at this site. There was little diversity in organisms found at this site. An unknown gastropod species, identified to be a dextral snail, represented over 86% of the collection. The lack of identification does limit the ability to evaluate this taxa's tolerance to degradation, but the severe limitation of diversity within the macroinvertebrate community together with the absence of any identifiable intolerant organisms led to the conclusion that anthropogenic disturbance has severely limited water and habitat quality at this site.

FIGURE 61. Site 4 sampling location on Juday Ditch.

Site 5 - Blue Ditch. The QHEI score for this site was 25.5, the lowest score of the study. The substrate was comprised of 50% sand, 35% gravel, and 15% cobble and was moderately embedded with silt. The site was directly adjacent to a cornfield on the left bank while grassy old-field vegetation dominated the right bank riparian zone (Figure 62). Trees and other woody vegetation were present within the reach further downstream but were not the dominant riparian zone vegetation for the site. Some aquatic vegetation was observed within the channel, but otherwise the stream had no signs of habitat cover or canopy shading. The ditch was about 6 m wide with slow flow, and no riffle development or other morphological diversity was observed. The mIBI score (3.5) was indicative of an impaired macroinvertebrate community. The very tolerant hemipteran family *Corixidae* dominated the insect sample. Members of the *Corixidae* taxon breath air and tend to tolerate habitat degradation. Their dominance lowered the HBI metric of the mIBI score. The ephemeropteran family *Baetidae* was also a prevalent taxon in the community. This family is considered to be relatively intolerant compared to *Corixidae*. The presence of *Baetidae* benefited the mIBI score; however, the score still indicated moderate water and habitat quality impairment.

FIGURE 62. Site 5 sampling location on Blue Ditch.

Site 6 - Solomon Creek. The QHEI score for this site was 43, the second highest score assessed during the study. Solomon Creek was 2.5 feet deep at this site due to available pool habitat (Figure 57). The in-stream and canopy cover at this site contributed to the higher score. Woody debris, undercut root wads, deep pools, and overhanging vegetation were all present, providing habitat diversity within the stream (Figure 63). When facing upstream, woody vegetation comprised the right bank and buffered it from the adjacent cornfield. The left bank consisted of grassy vegetation which provides less filtration capacity. Both pool and riffle development was observed at the site further contributing to habitat quality. The substrate consisted of 40% sand, 40% gravel, and 20% silt. The heavy siltation and extensive embeddedness of the substrate at this site substantially lowered the substrate score of the QHEI (3.5 out of 20 possible points). The mIBI score for Site 6 (5.5) reflected the higher quality habitat at this site and indicated only a "slightly" impaired system. The *Baetidae* family was the dominant taxon at this site, comprising 60% for the community. This taxon is relatively intolerant to habitat degradation, indicating a healthier community. The presence of other similarly intolerant macroinvertebrates, like individuals of the *Ephemeroptera* and *Trichoptera* orders, contributed to the higher mIBI score. Overall, the site had relatively high taxa diversity. Low community diversity detracted from the mIBI score.

FIGURE 63. Site 6 sampling location on Solomon Creek.

Site 7 - Solomon Creek. Substrate degradation was evident at Site 7 resulting in a QHEI of 37.5. Silt, sand, and clay dominated the extensively embedded substrate surface. Bank erosion was evident in the stream reach, which was straight and channelized. A forested riparian zone was present on both banks of the channel providing runoff filtration capabilities and canopy cover (Figure 64). Facing upstream, the right bank had only a narrow strip of trees to buffer the stream from an adjacent mowed field, while the left bank was extensively forested. In-stream cover of woody debris, overhanging vegetation, and undercut root wads contributed to habitat diversity. Pool and riffle development, although poor, further contributed to the total QHEI score. Like Site 6, this site was one of the deeper sites with a depth of 2.5 feet at cross-section (Figure 57). The presence of these morphological features indicated a more diverse habitat, but the pool, riffle, and substrate quality at the site were rather poor. The mIBI score for the site was 4.75, indicating "slight" system impairment. The score was influenced by the dominance of two relatively intolerant taxa, the amphipod family *Gammaridae* and the trichopteran *Hydropsychidae*, which both have a tolerance rating of 4.

FIGURE 64. Site 7 sampling location on Solomon Creek.

Site 8 - Solomon Creek. Site 8 also received the lowest QHEI score of the study (25.5). It is important to note that there was a loosely constructed rock dam under the bridge that marked the site. Flow was noticeably impounded upstream of this dam where sampling was conducted. Heavy siltation noted during the habitat evaluation may have been an artifact of the dam. The extensive embeddedness and poor substrate composition of sand and muck resulted in the worst substrate score of the study receiving only 1 of the possible 20 points. Although the riparian zone was comprised of trees and shrubby vegetation (Figure 65), this zone was very narrow on the right side providing little buffering from the adjacent cornfield. Channel morphology was poor, and no riffle development was evident due to the impounded conditions. The mIBI score for the site was 3.3, reflecting a “moderately” impaired community. The site supported a large diversity of macroinvertebrate taxa, and the dominant family was the moderately tolerant *Gammaridae.* A substantial portion of the community was composed of *Corixidae*, a pollution-tolerant taxon. The lack of representative members of healthy communities reduced the overall score.

FIGURE 65. Site 8 sampling location on Solomon Creek.

Site 9 - Dry Run. Poor substrate and little habitat diversity within the stream channel were the most noticeable impairments at Site 9. The QHEI score was 34.5. Heavy siltation was evident, and the substrate was predominantly sand. The channel was choked with grasses and aquatic algae, which provided moderate in-stream and canopy cover. The narrow riparian zone consisted of mostly grasses and shrubby vegetation (Figure 66). Riffle development and sinuosity were non-existent indicating little recovery from past channelization. The mIBI score for the site was the lowest of the study. The 0.75 score indicates a "severely" impaired macroinvertebrate community. The dominant macroinvertebrate taxon was the dipteran family *Chironomidae*, which comprised over 60% of the community. These organisms are considered to be relatively tolerant and are indicative of degradation when found in large proportions. Low taxa diversity and the low representation of EPT taxa were also reflected in the low mIBI score.

FIGURE 66. Site 9 sampling location on Dry Run.

Macroinvertebrate and Habitat Discussion

The overall evaluation of biotic health and habitat quality in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds indicates that these waterways are moderately to severely degraded. Each of the study sites lacked at least one of the key elements of natural healthy stream habitats. These missing key elements limit the ecological functionality of these systems. The QHEI evaluations revealed poor substrate quality in watershed streams. Additionally, QHEI scores pointed out the lack of riffle development within the stream channels. These factors are critical for habitat diversity and biological integrity in stream ecosystems. In the Whetten Ditch, Solomon Creek, and Dry Run Watersheds, poor mIBI scores reflected impacted stream habitat quality.

Heavy sediment loading was an apparent factor in the degradation of substrate quality in study streams. Several sites on the mainstem of Solomon Creek and Site 9 on Dry Run have experienced significant levels of siltation. Accordingly, substrate scores ranged from 1-8.5 of a possible 20 points. Extensive substrate embeddedness severely limits habitat diversity within the stream channel by filling in and closing off porous areas that offer refuge for a variety of aquatic organisms. This heavy sediment loading is reflected in the poor substrate scores of the QHEI evaluations.

Channel alterations such as ditching, dredging, straightening and other modifications also affect stream habitat diversity. Changing the natural stream morphology (shape) impacts riffle and pool development, resulting in fewer habitat types for macroinvertebrate and fish colonization. Deep pools and shallow riffles can also affect chemical characteristics of flowing water as well. As reflected in the QHEI evaluations and stream cross-sections, all of the study reaches have been impacted by channelization. Steep stream banks, straight reaches, and dredge spoil piles indicate that these streams have been modified and lack natural sinuosity and development.

Another important aspect of good habitat quality that is conspicuously missing from many of the study sites is an effective riparian zone to buffer stream systems from surrounding land use. Stable woody vegetation zones that naturally form adjacent to streams and other waterways provide distinct functions that enhance habitat quality (Ohio EPA, 1999). Primarily, this zone slows runoff, collects sediment, and stores nutrients that would otherwise be loaded into the stream system. Poor QHEI and mIBI scores are also probably related to riparian zone absence. Site 2 on Solomon Creek benefited from a healthy riparian zone and also supported a healthy macroinvertebrate community. Extensive woody vegetation around streams provides additional habitat in the form of logs and woody debris, overhanging vegetation, and submerged root wads. Riparian vegetation provides canopy cover that shades the stream and minimizes thermal inputs. Shade can limit extensive, nuisance levels of aquatic vegetation that are dependent upon sufficient levels of solar radiation. Unfiltered nutrient-rich runoff can also promote vegetation and algal growth. Mowed grassy vegetation adjacent to streams does little to slow flows into the stream and therefore is less capable of trapping sediments and nutrients. Based on observations made during sampling events, the quality and quantity of riparian zone vegetation is moderately to severely limited.

Each of these physical factors contributes to habitat quality, and their absence or degradation at most of the sites is related to macroinvertebrate community structure. With the exception of Site 2 and Site 6, mIBI scores were low for study area streams. Sites 2 and 6 did receive the highest QHEI scores, suggesting that habitat factors do have an impact on the quality of ecological communities. The other seven sites received mIBI scores indicating “moderate” to “severe” impairment. In a healthy stream system, a diverse community of both tolerant and intolerant taxa is expected. Impacts of degradation will tend to limit or eliminate organisms that are incapable of persisting in such systems. In general, tolerant taxa dominated samples and leading to lower mIBI scores. In fact, Sites 2, 6, and 7 were the only sites to score above a zero for the HBI metric which directly rates community tolerance.

It is important to remember that overall watershed condition will impact habitat and biotic quality. In fact, scientific data suggest that watershed condition may have a greater influence on macroinvertebrate metrics than local riparian land use (Weigel et al., 2000). So although local streamside best management practices are important, a broader, watershed-level approach is necessary to effectively address biotic integrity and stream health. An additional study by Osmond and Gale (1995) showed that large-scale reductions in agricultural non-point source pollution are necessary for stream health improvement. Examples of working at a watershed-level include coordinating with producers to implement nutrient, pesticide, tillage and coordinated resource management plans.

Macroinvertebrate and Habitat Summary

Because many of the stream reaches surveyed had been channelized in the past, many stream characteristics were absent or severely deficient as indicated by the low QHEI scores. The overall habitat degradation components that impair conditions for aquatic life within the Whetten Ditch, Solomon Creek, and Dry Run Watersheds were:

- Poor pool-riffle development: deep places (pools) and shallow places (riffles) within a stream reach offer habitat variety for aquatic organisms and can impact certain chemical characteristics of flowing water like temperature, dissolved oxygen concentrations, and suspended sediment load.
- Siltation/substrate embeddedness: excessive loading of fine sediments and silt clogs or embeds the substrate spaces destroying habitat for aquatic invertebrates and fish.
- Channel alterations: ditching, dredging, straightening, and other changes to channel structure can affect the ability of organisms to live in the stream.
- Poor in-stream cover: in-stream cover like undercut banks, overhanging vegetation, woody debris, and aquatic vegetation offer protection and habitat for aquatic organisms. Like pools and riffles, in-stream cover also influences certain chemical characteristics like temperature and dissolved oxygen.
- Lack of or very narrow riparian zone: farming and other land use practices very near or even at the stream's edge decrease canopy cover over the stream allowing for increased thermal pollution inputs to the stream. Additionally, narrow riparian areas do not filter or infiltrate runoff as efficiently as filter areas that are at least 30 feet wide (NRCS, 2000).

These habitat characteristics are important for the aquatic life that inhabits streams. As one would expect, the impaired habitat conditions in the study streams were reflected in mIBI scores. In general, sites with reduced habitat fostered macroinvertebrate communities of higher pollution tolerance and lower diversity. All QHEI scores fell below the level of 60 that has been found to be conducive to aquatic life, and mIBI scores ranged from "severely" impaired to "slightly" impaired.

Relationships Among Chemical, Biological, and Habitat Characteristics

Chemical parameters and biological and habitat indices were analyzed for relationships that could provide additional insight into mechanisms governing impairment within the subwatersheds. The following list includes parameters for which no statistically significant linear relationship was found:

- QHEI Score vs. mIBI Score
- QHEI Score vs. TSS (mg/l)
- QHEI Score vs. Discharge (cfs)
- QHEI Score vs. Turbidity (NTU)
- QHEI Substrate Score vs. mIBI Score
- QHEI Cover Score vs. mIBI Score
- QHEI Riparian Score vs. mIBI Score
- QHEI Riffle Score vs. mIBI Score
- QHEI Substrate Score vs. TSS (mg/L)
- mIBI Score vs. Turbidity (NTU)
- mIBI Score vs. NH_3 (mg/l)

- mIBI Score vs. SRP (mg/l)
- mIBI Score vs. TP (mg/l)
- mIBI Score vs. TSS (mg/l)

One possible explanation for this lack of correlation is that these creeks are, in general, highly modified, somewhat artificial drainage ditches, and consequently might not reflect natural relationships among parameters of water quality, habitat quality, and biological health. In many cases, the response variable showed such a limited range (due to being highly modified) that correlation was impossible.

Three statistically significant positive correlations were found among physical, chemical, and biological parameters:

- mIBI Score vs. Discharge (Figure 67)
- mIBI Score vs. NO_3^- (Figure 68)
- QHEI vs. HBI (Figure 69)

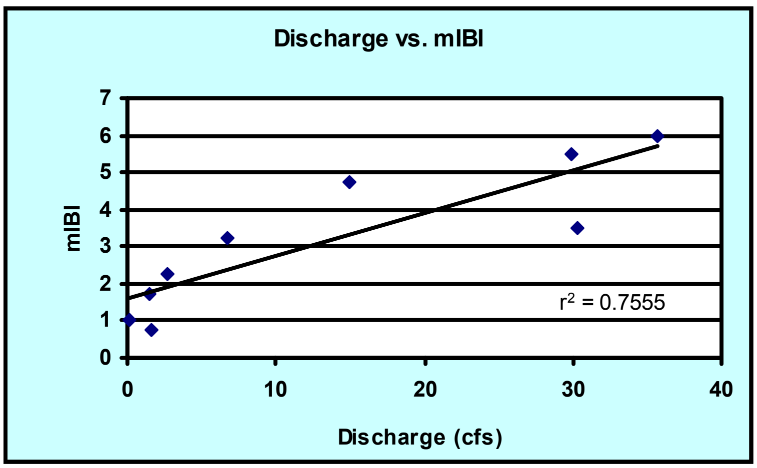

FIGURE 67. Statistically significant relationship (p=0.002) between discharge and mIBI scores measured for the Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

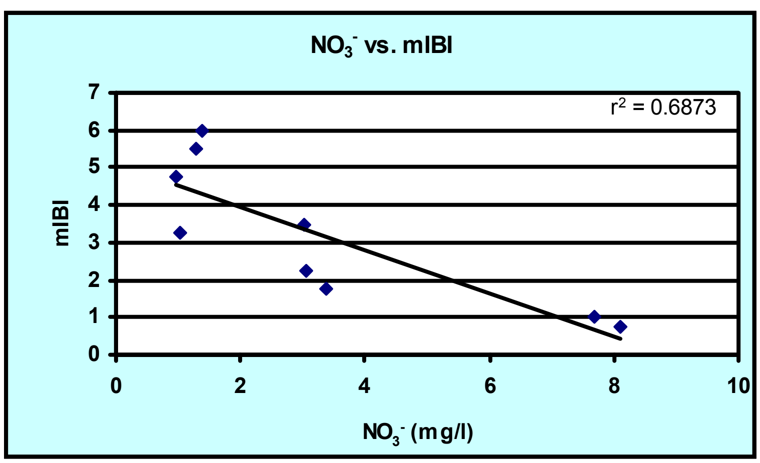

FIGURE 68. Statistically significant relationship (p=0.006) between nitrate-nitrogen concentration and mIBI scores measured for the Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

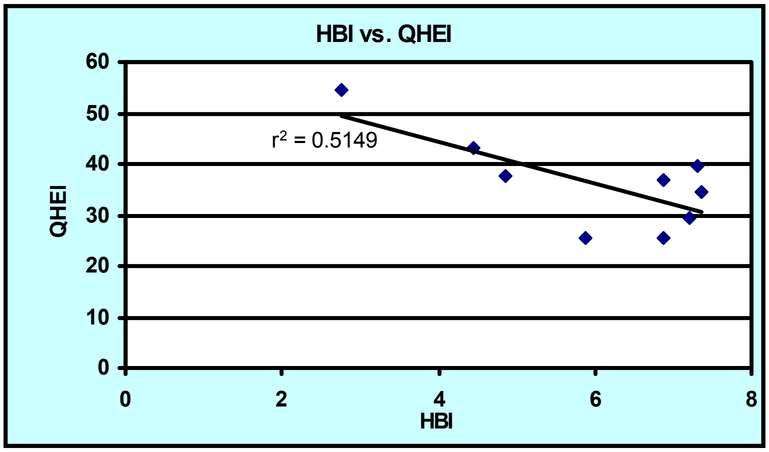

FIGURE 69. Statistically significant relationship (p=0.03) between the HBI and the QHEI scores measured for the Whetten Ditch, Solomon Creek, and Dry Run Watershed streams.

The relationship illustrated between discharge and mIBI (Figure 67) is expected based on the importance of flow and stream dynamics. Flowing water brings a continuous supply of nutrients and food particles to stream biota, not to mention increased dissolved oxygen. For example, the concentrations of dissolved organic matter (DOM) increase as a function of discharge in many streams (Allan 1995). The concentration of particulate organic matter (POM) increases with the first flush of a storm event and then becomes diluted with additional discharge as the supply of POM is exhausted. In systems like Dry Run, Solomon Creek and Whetten Ditch, where there is an overabundance of organic matter present in the stream and its substrate, higher discharges can mobilize and transport the POM. As Hynes (1970) stated in his classic work, current makes the water "physiologically richer" because of its constant renewal of materials in solution near the surfaces of stream organisms.

The Ohio EPA found that degradation of the biotic community was observable when median nitrate-nitrogen concentrations exceeded 3-4 mg/l (Ohio EPA, 1999). Low-flow nutrient data are usually used since low-flow conditions represent residual nutrient concentrations (Ohio EPA, 1999). The low-flow nitrate concentrations of >50% of the study streams exceeded 3 mg/l, and the relationship shown in Figure 68 results: Higher nitrate concentrations fostered insect communities of higher tolerance and lower diversity.

The HBI and QHEI were inversely related, indicating that a lower QHEI score corresponded to a more tolerant macroinvertebrate community (Figure 69). Based on this data, it is reasonable to expect improvements in biotic health (as measured by organism tolerance to pollution) if habitat restoration projects are undertaken.

PHOSPHORUS MODELING

Since phosphorus is the limiting nutrient in most lakes and reservoirs, watershed management programs often target phosphorus as a nutrient to control. Because of this, we have used a phosphorus model to estimate the dynamics of this important nutrient in these watersheds.

The limited scope of this LARE study did not allow us to determine phosphorus inputs and outputs outright. Therefore, we have used a standard phosphorus model to estimate the phosphorus budget. Reckhow et al. (1980) compiled phosphorus loss rates from various land use activities as determined by a number of different studies and calculated phosphorus export coefficients for each land use in the watershed. We used mid-range estimates of these phosphorus export coefficient values for most watershed land uses (Table 53). Because of the relatively high use of conservation tillage practices in Elkhart and Noble Counties, we lowered the expected phosphorus export coefficient from row crop agriculture from 2.0 kg/ha yr to 1.4 kg/ha yr in our model.

TABLE 53. Phosphorus Export Coefficients (units are kg/hectare-yr except the septic category, which are kg/capita-yr).

Estimate Range	Row Crops	Non-Row	Pasture	Forest	Precip.	Urban	Septic
High	5.0	1.5	2.5	0.3	0.6	3.0	1.8
Mid	2.0	0.8	0.9	0.2	0.3	1.0	0.4-0.9
Low	1.0	0.5	0.1	0.1	0.15	0.5	0.3

Source: Reckhow et al. (1980)

Phosphorus export coefficients are expressed as kilograms of phosphorus lost per hectare of land per year. These are multiplied by the amounts of land in each of the land use category to derive an estimate of annual phosphorus export (as kg/year) for each land use per subwatershed (Table 54).

Because row crop agriculture is the dominant land use within each of the subwatersheds, the proportional mass of phosphorus estimated from row cropland is also high – over 96% of the total estimated phosphorus loss. The percentage phosphorus loss due to row crops ranges from a low of 95% in the Juday Ditch (4) and Solomon Creek Headwaters (8) Subwatersheds to a high of 99% in the Dry Run (9) and Blue Ditch (5) Subwatersheds. When the data have been normalized for subwatershed area (Table 55), Blue Ditch and Dry Run contribute the largest amounts of phosphorus per unit area per year. The model estimates that 16,563 kilograms (18.2 tons) of phosphorus is lost from lands within the project area each year. Significant reduction of phosphorus loading to local streams will necessitate additional management of agricultural sources.

TABLE 54. Results of phosphorus export modeling by subwatershed given in kg/yr.

	P-Export Coefficient	**Whetten Ditch (1)**	**Solomon Cr. West (2)**	**Hire Ditch (3)**	**Juday Ditch (4)**	**Blue Ditch (5)**	**Meyer/ Cromwell Ditch (6)**	**Solomon Cr. East (7)**	**Solomon Cr. Head. (8)**	**Dry Run (9)**	**TOTALS**
Agriculture Pasture/Grassland	0.9	22.8	37.5	9.0	12.2	0.0	28.4	40.8	136.1	3.1	290.0
Agriculture Row Crop	1.4	1519.7	1650.8	1256.0	427.5	677.7	2250.7	2357.0	4394.4	1441.1	15974.9
Developed Non-Vegetated	1.0	2.7	2.0	0.0	0.0	1.0	4.3	0.0	0.0	0.0	9.9
High Density Urban	1.5	0.0	0.0	0.0	0.0	0.0	5.3	4.8	0.0	0.0	10.1
Low Density Urban	1.0	1.6	0.0	0.0	0.0	0.0	20.7	13.1	3.7	0.0	39.1
Deciduous Forested Wetland	0.1	3.1	3.3	3.3	1.2	0.5	1.3	2.5	6.9	3.3	25.5
Deciduous Herbaceous Wetland	0.1	2.1	1.1	0.4	0.4	0.4	2.8	0.2	6.6	0.3	14.3
Deciduous Shrub Wetland	0.1	0.3	0.2	0.0	0.1	0.3	0.5	0.0	1.6	0.0	3.0
Sparsely Vegetated Point Bar/Flood Zone/Shoreline	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.4
Deciduous Forest	0.2	14.2	14.1	24.8	7.4	1.8	32.9	25.9	55.2	9.4	185.7
Evergreen Forest	0.15	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	1.2
Deciduous Shrubland	0.15	1.9	0.2	0.2	0.0	0.0	3.3	1.4	2.2	0.2	9.3
Open Water	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		**1569.4**	**1709.2**	**1293.7**	**448.8**	**681.7**	**2350.4**	**2445.7**	**4606.8**	**1457.5**	**16563.3**

[a]From Reckhow et al. (1980)
[b]All units are kilograms phosphorus per year

TABLE 55. Results of phosphorus export modeling by subwatershed given in kg/ha-yr.

Subwatershed	Phosphorus Export (kg/ha-yr)
Whetten Ditch (1)	1.10
Solomon Creek West (2)	1.28
Hire Ditch (3)	1.21
Juday Ditch (4)	1.20
Blue Ditch (5)	1.35
Meyer/Cromwell Ditch (6)	1.24
Solomon Creek East (7)	1.28
Solomon Creek Headwaters (8)	1.23
Dry Run (9)	1.31

RECOMMENDATIONS

All of the smaller watersheds within the Whetten Ditch, Solomon Creek, and Dry Run Watersheds could benefit from land treatment and best management strategies as already described in detail in the Watershed Investigation Section. Finances, time, manpower, and other restraints make it impossible to implement all of these management techniques at once. Thus, it is necessary to prioritize the recommendations.

These prioritizations and recommendations are simply guidelines based on conditions documented during this study. These conditions may change as land use within the watershed changes. Management efforts may need to be prioritized differently based on project feasibility and individual landowner willingness to participate. To ensure maximum participation in any management effort, all watershed stakeholders should be allowed to participate in prioritizing the management efforts in the watershed.

It is also important to note that even if all stakeholders agree that this is the best prioritization to meet their needs, action need not be taken in this order. Some of the smaller, less expensive recommendations may be implemented while funds are raised to implement some of the larger projects. Many of the larger projects will require feasibility work to ensure landowner willingness to participate in the project. In some cases, it may be necessary to attain regulatory approval as well. Landowner endorsement and regulatory approval along with stakeholder input may ultimately determine the prioritization of management efforts.

Results from the mapping exercises, the aerial tour, the windshield survey, water quality sampling, biological sampling, habitat sampling, and the modeling exercise were used to prioritize subwatersheds for future work. The subwatersheds are discussed in order of priority. It is also important to note that in order to make prioritizations, it is necessary to make some generalizations. Additional general recommendations, like innovative riparian management system use and recommended practices for homeowners, follow the primary recommendations section. Many of these recommendations may already be in practice; however, for the sake of thoroughness, they are reiterated here.

Prioritization

Based on the findings of this study, the order of prioritization for work, projects, and program enrollment within the Whetten Ditch, Solomon Creek, and Dry Run Watersheds should be:

1. Dry Run Subwatershed
2. Whetten Ditch Subwatershed
3. Solomon Creek Headwaters Subwatershed
4. Juday Ditch Subwatershed
5. Blue Ditch Subwatershed
6. Meyer/Cromwell Ditch Subwatershed
7. Hire Ditch Subwatershed
8. Solomon Creek East Subwatershed
9. Solomon Creek West Subwatershed

Dry Run (9) is of top priority due to high pollutant loading rates especially for phosphorus and *E. coli*. The 319 Program study of all watersheds in Elkhart County by Lawson-Fisher ranked Dry Run as the sixth priority watershed for sewer installation due to elevated stream *E. coli* levels. The mIBI score of 0.75 was the lowest score calculated for any stream during the study, and the QHEI score was also poor. Sixteen potential project sites were located during aerial and windshield tours of its drainage.

Whetten Ditch (1) is also of high priority due to high storm flow loads of suspended solids and elevated *E. coli* regardless of flow stage. The Whetten Ditch Watershed was fifth on Lawson-Fisher's priority list for sewer installation in Elkhart County due to consistently elevated *E. coli* levels. The QHEI score (29.5 of 100) and mIBI score (1.75 of 8) were also among the lowest estimated during the study. Additionally, the HEL:CRP ration was high indicating that per acre of HEL, only a small portion receives conservation treatment via the CRP.

The Solomon Creek Headwaters (8) Subwatershed was ranked third on the priority list because a larger percentage (~29%) of cropped land in the basin is highly erodible when compared to other drainage basins in the study area. Additionally, habitat as scored using the QHEI indicates severe non-support of aquatic life uses (25.5 points of a possible 100). TP loading during the storm event sampled during this study was also elevated. The Solomon Creek Headwaters Subwatershed would make an excellent candidate for Watershed Land Treatment projects, since projects constructed in the headwaters can benefit the entire watershed and since the study identified 20 areas where conservation projects may benefit water quality.

Juday Ditch (4) is also listed as a priority subwatershed. During storm flows, this ditch loaded more suspended solids, total phosphorus, and *E. coli* to Solomon Creek per unit area than any other study stream. The mIBI indicated "severe" impairment, and Juday Ditch loaded disproportionate amounts of ammonia, TKN, TP, and TSS relative to flow rate.

Blue Ditch (5) loaded disproportionately more nutrients and sediment relative to flow than any other stream based on samples collected during the study. The QHEI score tied that estimated for Solomon Creek at Site 8, the lowest for any study reach. Additionally, the phosphorus loading model estimated that annual phosphorus loading per unit area from the Blue Ditch Subwatershed was higher than loading from any other study drainage (1.35 kg P/ha-yr).

The remaining four subwatersheds are of lower priority because they were generally responsible for lower amounts of pollutant loading and/or generally already contain more protected land in CRP relative to HEL than the subwatersheds of top priority. However, projects and landowner participation in these areas should not be discouraged. As will be discussed in the Funding Sources and Watershed Resources Section, the primary obstacle facing watershed projects is typically landowner willingness to participate (Osmond and Gale, 1995). Management and participation certainly should be encouraged in the remaining four subwatersheds of lower overall priority.

<u>Primary Recommendations</u>

1. Apply for Lake and River Enhancement (LARE) Watershed Land Treatment Funds to implement recommended BMPs and projects discussed for each subwatershed (Tables

33-40) based on subwatershed priority. Some of these projects included: wetland restoration, filter strip installation, allowing for natural riparian vegetation growth, bank stabilization, livestock fencing, information and education efforts, buffer zone establishment, revegetation of exposed areas, and grassed waterway construction. This work should focus on interested landowners in identified critical areas first.

2. Coordinate the projects referenced in recommendation #1 with the county drainage boards to ensure that the project meets goals of both the Soil and Water Conservation District (SWCD) and the drainage board. For example, a SWCD tree-planting project in an area that is scheduled for drainage project de-brushing will not result in the optimum use of resources. In fact, a landowner may be more willing to participate in a cost-share program following ditch maintenance projects. Although none of the ditches is currently "on the books" for dredging, Hire Ditch from CR 43 northwest to Solomon Creek has been petitioned for maintenance with work slated for sometime "within the next few years". It is recommended that the SWCD work closely with the drainage boards to ensure that conservation practices advocated in the Indiana Drainage Handbook (Burke, 1996) are followed when planning and implementing projects. These conservation practices recommend tree preservation, vegetative stabilization and seeding, stream environment enhancement, and tree replacement even near regulated drains. Additionally, the Indiana Lakes Management Work Group, an Indiana Legislature authorized and governor appointed group, also recommended that "drainage boards…implement all possible best management practices as indicated in the Indiana Drainage Handbook" (Case and Seng, 1999). The Group further suggested that the 1965 Indiana Drainage code (IC 36-9-27) be updated to "allow ditch maintenance assessments to be used to cost-share preventative measures such as streambank stabilization, riparian vegetation, and stable livestock access and stream crossings" and to "require drainage boards to develop a master plan (based on sound watershed management practices and with input from landowners) for each drain that proactively identifies sections of stream where landowners can restore protective riparian vegetation along stream sections that are never accessed for drain maintenance".
3. Extend management to the watershed-level. Although streamside localized BMPs are important, research conducted in Wisconsin shows that the biotic community mostly responds to large-scale watershed influences rather than local riparian land use changes (Weigel et al., 2000). Examples of working at the watershed-level include coordinating with producers to implement nutrient, pesticide, tillage, and coordinated resource management plans. It is important to note that the LARE Program will provide cost-share incentives for large-scale land practices like conservation tillage. Large-scale reductions in agricultural non-point source pollutions are necessary for stream health improvement (Osmond and Gale, 1995).
4. Provide information about streams within the Whetten Ditch, Solomon Creek, and Dry Run Watersheds to local landowners. Landowners will be more likely to conserve and protect the creeks if they understand their value. The outreach program could include pointers on how landowners themselves can help protect the waterways.

General Recommendations

1. Develop a watershed or land use management plan. A watershed management plan documents current conditions within a watershed, sets forth goals for the watershed based

on stakeholders' desires, develops a plan of how to reach those goals, and provides for monitoring progress towards the goal. To be effective, all stakeholders must be included in the plan's development.

2. Before initiating watershed treatment projects, consider conducting a survey of landowners in the watershed to determine landowners' concern for water quality problems, to evaluate landowers' opinions of management systems, and to quantify the value of surface and groundwater quality improvement. Use this information to work with interested landowners to formulate individual Resource Management Plans.
3. Reach out to a school or other volunteer group to set up volunteer monitoring within the watershed through the Hoosier Riverwatch Program. This data will be a valuable resource by which to evaluate the success of projects implemented in the area.
4. Consider using innovative riparian management systems similar to the one discussed earlier in the Best Management Practice Section. Modified systems of this type would be especially beneficial for use in critical or vulnerable stream reaches where they could significantly impact non-point source pollution. Several critical stream reaches were identified by this study.
5. Invite producers and other landowners out to successful project sites. There is no better advertisement than a success story. Focus on information dissemination and transfer by scheduling on-site field days during non-busy seasons.
6. Work with a bulk seed distributor to make native plant seed available in large quantities at low prices.
7. Work with the Elkhart County Health Department to ensure proper siting and engineering of septic systems. The use of alternative technology should be encouraged when conditions may compromise proper waste treatment. IDNR and USDA soil scientists in the area are a valuable resource for expertise in characterizing soils for septic use. Their knowledge could be tapped for future building and siting of systems. If building was necessary on a site where conditions were not suitable for a traditional system, alternative technology could be constructed and the site used as a demonstration and education/outreach tool.
8. Specific District activities identified during the study include:
    a) Working with landowners that have drainage tiles that directly convey water to streams in the watershed to install treatment wetlands or filter areas so that drainage water receives both mechanical and chemical treatment prior to discharge.
    b) Scheduling meetings with active land developers in the area to encourage the use of conservation design when planning new development areas.
    c) Working with New Paris Speedway owners and operators to ensure that best septic system management practices are used and that racetrack runoff is properly controlled.
9. Homeowners in the watershed should:
    a) Avoid lawn fertilizing near the stream's edge.
    b) Examine all drains that lead from roads, driveways, or rooftops to the stream, and consider alternate routes for these drains that would filter pollutants before they reach the water.
    c) Keep organic debris like lawn clippings, leaves, and animal waste out of the water and away from riparian areas.

d) Avoid mowing up to the stream's edge; allow natural riparian vegetation growth.
e) Properly maintain on-site wastewater treatment systems. Systems should be pumped regularly and leach fields should be properly cared for. Undue pressure on systems may be alleviated by water conservation practices as well.
f) Maintain field drainage tiles and use filter strips around tile risers.
g) Consider working with the Elkhart County NRCS to formulate a Resource Management Plan for each individual property.

FUNDING SOURCES AND WATERSHED RESOURCES

Funding and other resources are important for the actual implementation of recommended management practices in a watershed. Several cost share and grant programs are available to help offset costs of watershed projects. Additionally, both human and material resources may be available in the watershed.

Funding Sources

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Lake associations and/or Soil and Water Conservation Districts (SWCDs) can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake and watershed associations for watershed management.

Lake and River Enhancement Program (LARE)

This is the program that funded this diagnostic study. LARE is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a specific project or $300,000 for all projects on a specific lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project. LARE also has a "watershed land treatment" component that can provide grants to SWCDs for multi-year projects. The funds are available on a cost-sharing basis with landowners who implement various BMPs. The watershed land treatment program is highly recommended as a project funding source for the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant

The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must be listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement.

Section 104(b)(3) NPDES Related State Program Grants
Section 104(b)(3) of the Clean Water Act gives authority to a grant program called the National Pollutant Discharge Elimination System (NPDES) Related State Program Grants. These grants provide money for developing, implementing, and demonstrating new concepts or requirements that will improve the effectiveness of the NPDES permit program that regulates point source discharges of water pollution. Projects that qualify for Section 104(b)(3) grants involve water pollution sources and activities regulated by the NPDES program. The awarded amount can vary by project and there is a required 5% match.

Section 205(j) Water Quality Management Planning Grants
Funds allocated by Section 205(j) of the Clean Water Act are granted for water quality management planning and design. Grants are given to municipal governments, county governments, regional planning commissions, and other public organizations for researching point and non-point source pollution problems and developing plans to deal with the problems. According to the IDEM Office of Water Quality website: "The Section 205(j) program provides for projects that gather and map information on non-point and point source water pollution, develop recommendations for increasing the involvement of environmental and civic organizations in watershed planning and implementation activities, and implement watershed management plans. No match is required. For more information on the 310, 104(b)(3), and 205(j) grants, please see the IDEM website
http://www.in.gov/idem/water/planbr/wsm/Section205j_main.html.

Other Federal Grant Programs
The USDA and EPA award research and project initiation grants through the US National Research Initiative Competitive Grants Program and the Agriculture in Concert with the Environment Program.

Watershed Protection and Flood Prevention Program
The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture (USDA) and is administered by the Natural Resources Conservation Service (NRCS). Funding targets a variety of watershed activities including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program
As already discussed, the Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency (FSA). CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good wildlife habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Participants in the program receive cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the NRCS. WRP is a subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

North American Wetland Conservation Act Grant Program

The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish and other wildlife. The match for this program is on a 1:1 basis.

Wildlife Habitat Incentive Program

The Wildlife Incentive Program (WHIP) is funded by the USDA and administered by the NRCS. This program provides support to landowners to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary program designed to provide assistance to producers to establish conservation practices in target areas where significant natural resource concerns exist. Eligible land includes cropland, rangeland, pasture, and forestland, and preference is given to applications which propose BMP installation that benefits wildlife. EQIP offers cost share and technical assistance on tracts that are not eligible for continuous CRP enrollment. Certain BMPs receive up to 75% cost share. In return, the producer agrees to withhold the land from production for five years. Practices that typically benefit wildlife include: grassed waterways, grass filter strips, conservation cover, tree planting, pasture and hay planting, and field borders. Best fertilizer and pesticide management practices are also eligible for EQIP cost-share.

Farmland Protection Program

The Farmland Protection Program (FPP) provides funds to help purchase development rights in order to keep productive farmland in use. The goals FPP are: to protect valuable, prime farmland from unruly urbanization and development; to preserve farmland for future generations; to support a way of life for rural communities; and to protect farmland for long-term food security.

Debt for Nature

Debt for Nature is a voluntary program that allows certain FSA borrowers to enter into 10-year, 30-year, or 50-year contracts to cancel a portion of their FSA debts in exchange for devoting eligible acreage to conservation, recreation, or wildlife practices. Eligible acreage includes: wetlands, highly erodible lands, streams and their riparian areas, endangered species, or significant wildlife habitat, land in 100-year floodplains, areas of high water quality or scenic value, aquifer recharge zones, areas containing soil not suited for cultivation, and areas adjacent or within administered conservation areas.

Non-Profit Conservation Advocacy Group Grants

Various non-profit conservation advocacy groups provide funding for projects and land purchases that involve resource conservation. Ducks Unlimited and Pheasants Forever are two such organizations that dedicate millions of dollars per year to projects that promote and/or create wildlife habitat.

Watershed Resources

An important but often overlooked factor in accomplishing goals and completing projects in any watershed is resources within the watershed itself. These resources may be people giving of their time, local schools participating in projects, companies giving materials for project construction, or other donations. This study documents some of these available resources for the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. It is important to note that this list is not all-inclusive, and some groups and donors may have been missed.

Watershed Coordinator

The Indiana Department of Environmental Management (IDEM) and the USDA cosponsor three regional watershed conservationist positions. The watershed conservationist is an advocate for watershed-level work in the region. Watershed conservationists can help direct actions of groups and stakeholders who are interested in working together to address problems in their watershed. They can help with everything from structuring public meetings to assisting with the compilation of a Watershed Management Plan. Their wealth of knowledge includes ideas about how to work with and respect all stakeholders in order to find the best plan for natural resource conservation within your watershed. Matt Jarvis is the regional watershed conservationist for the northern third of Indiana and has an office in the NRCS office in Delphi, Indiana. His contact information is found below.

Matt Jarvis
Regional Watershed Conservationist
Natural Resources Conservation Service
1523 N. US Highway 421, Suite 2
Delphi, Indiana 46923-9396
(765) 564-4480
matt.jarvis@in.usda.gov

Coordinated Resource Management

The Coordinated Resource Management (CRM) process is an organized approach to identification of local concerns, evaluation of natural resources, development of alternative actions, assistance from technical specialists, implementation of a selected alternative, evaluation of implementation activities, and involvement of all interested parties who wish to participate in watershed action. The goal is an effective Watershed Management Plan through the establishment of common goals and actions to achieve those goals. Further CRM information and its complementary Watershed Action Guide can be downloaded from the USDA/NRCS website at http://www.in.nrcs.gov. The CRM gives guidance on how to plan with people to maximize benefits to the greatest number of people while enhancing or maintaining the natural resource.

Hoosier Riverwatch

The Hoosier Riverwatch Program was started in 1994 by the State of Indiana to increase public awareness of water quality issues and concerns. Riverwatch is a volunteer stream monitoring program sponsored by the IDNR Division of Soil Conservation in cooperation with Purdue University Agronomy Department. Any citizen interested in water quality may volunteer to take a short training session held from May through October. Water monitoring equipment may be supplied to nonprofit organizations, schools, or government agencies by an equipment grant. Additionally, many SWCD offices (including the Elkhart, Kosciusko, and Noble County SWCDs) have loaner equipment that can be borrowed. Several groups in the three counties actively participate in the Riverwatch Program. Table 56 contains information about groups that have conducted volunteer monitoring in the three counties. Because neither Whetten Ditch, Solomon Creek nor Dry Run have been monitored through the Hoosier Riverwatch Program, more participation should be advocated within the study watershed especially since loaner equipment is readily available. More detailed information is available via the Hoosier Riverwatch web site at http://www.state.in.us/dnr/soilcons/riverwatch/.

TABLE 56. Groups that have participated in the Hoosier Riverwatch volunteer monitoring program in Elkhart, Kosciusko, and Noble Counties.

County	Organization	City
Elkhart	Elkhart County SWCD	Goshen
Elkhart	Elkhart EnviroCorps	Elkhart
Elkhart	Goshen High School	Goshen
Elkhart	Model Elementary School	Goshen
Elkhart	Middlebury Elementary School	Middlebury
Elkhart	Memorial High School	Elkhart
Kosciusko	Kosciusko County SWCD	Warsaw
Kosciusko	Wawasee Area Conservancy Foundation	Syracuse
Noble	Noble County SWCD	Albion
Noble	High Lake Conservation Club	Albion
Noble	East Noble High School	Kendallville

Volunteer Groups

Volunteer groups can be instrumental in planning projects, implementing projects, and monitoring projects once they are installed. Although no streams in the study watershed have been monitored by Hoosier Riverwatch participants, both the Model Elementary School and Goshen High School have participated in the program. The two schools are located in Goshen and are close to the study watersheds. Involving the people living in the watershed, especially school-age children, is a good way to promote natural resource awareness and a good way to get data collected and projects completed. Oftentimes, data collected by volunteer groups may be the only available data for a watershed. This data is very valuable in helping to establish baseline trends with which to compare future samples.

Conservation Groups

The Elkhart Conservation Club is an active organization having paired with the Elkhart County SWCD for Hoosier Riverwatch and Project WET training and an elementary school field day. The group also stocks trout into Solomon Creek. Teaming with the club in the future to help raise citizens' and especially childrens' awareness of water quality issues in the area is highly recommended.

The EPA lists two other volunteer organizations active in Indiana that may have an interest in protecting water quality in the Solomon Creek area. The Friends of the St. Joe River Association, Inc. was established in 1994 to bring people of the St. Joseph River Watershed together to clean and restore the St. Joseph River and all its tributaries. The group has recently applied for 319 funding to complete a St. Joseph River Basin watershed management plan. Information about the organization is available at http://www.fotsjr.org/. Additionally, the St. Joseph River Basin Commission located in South Bend, Indiana is actively involved in water quality issues that pertain to the St. Joseph River particularly monitoring programs and information dissemination. They also act as a liaison to groups interested in river cleanup and volunteer monitoring. The commission publishes a quarterly newsletter and holds quarterly meetings at the Elkhart County Public Services Building in Goshen.

Purdue Agricultural Center (PAC) Research and Demonstration Projects

The Pinney and Northeast Purdue Agricultural Centers (PACs) participate in on-going agricultural research that is relevant to challenges producers face in northern Indiana. The Pinney PAC is located in Wanatah the Northeast PAC in Columbia City. Brian McGowan studies forestry and natural resource issues at the Northeast Center. Mr. McGowan is currently investigating the effects of filter strips on crop production via alterations in the community dynamics of arthropods, small mammals, and birds. He has also hosted demonstrations of windbreak and wetland planting possibilities at the center in Wanatah. His research may provide insight on future management techniques that could be applicable to the Solomon Creek area.

Obstacles for Watershed Projects

Although the current study did not directly identify obstacles or special challenges for watershed-level projects in the Whetten Ditch, Solomon Creek, or Dry Run Watersheds, data collected during a phone survey of hundreds of producers in the 21 Rural Clean Water Program (RCWP) project areas provides some information with respect to the most typical obstacle encountered in watershed projects: private landowner willingness to participate. The purpose of the survey was to evaluate difference between farmers who chose to participate in the RCWP projects and those who did not (Gale et al., 1993). Participation was positively correlated with the following factors: total acreage farmed, farm sales, property/equipment values, water pollution awareness, access to water quality/conservation materials and information, education level, willingness to take risks, availability of financial (cost-share) incentives, and level/frequency of one-to-one contact between project personnel and farmers (Osmond and Gale, 1995). (An example of a positive correlation would be that more producers participated if more cost-share incentives were available.) The study found that producers who were tenant farmers or were employed off-farm were less likely to participate in conservation programs. The main reason landowners did not participate was that they did not believe water quality to be a problem.

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APPENDICES

APPENDIX 1:

Detailed Land Use and Land Cover for the Study Subwatersheds

APPENDIX 1. Detailed Land Use and Land Cover for the Study Subwatersheds.

TABLE 1.1 Whetten Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	475.60	192.55	13.48
Emergent Herbaceous Wetland	16.70	6.76	0.47
Evergreen Forest	0.20	0.08	0.01
High Intensity Commercial/Industrial/Transport	0.70	0.28	0.02
Low Intensity Residential	2.20	0.89	0.06
Mixed Forest	0.10	0.04	0.00
Open Water	2.40	0.97	0.07
Pasture	361.40	146.32	10.25
Row Crops	2566.70	1039.15	72.77
Woody Wetland	101.30	41.01	2.87
TOTAL	**3527.30**	**1428.06**	**100.00**

TABLE 1.2 Solomon Creek West Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	100.70	40.77	3.04
Emergent Herbaceous Wetlands	28.20	11.42	0.85
High Intensity Commercial/Industrial/Transport	0.20	0.08	0.01
Pasture/Hay	330.60	133.85	9.98
Row Crops	2814.10	1139.31	84.98
Woody Wetlands	37.50	15.18	1.13
TOTAL	**3311.30**	**1340.61**	**100.00**

TABLE 1.3 Hire Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	302.20	122.35	11.43
Emergent Herbaceous Wetlands	4.70	1.90	0.18
Open Water	0.10	0.04	0.00
Pasture/Hay	140.20	56.76	5.30
Row Crops	2142.50	867.41	81.04
Woody Wetlands	53.90	21.82	2.04
TOTAL	**2643.60**	**1070.28**	**100.00**

TABLE 1.4 Juday Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	67.70	27.41	7.34
Emergent Herbaceous Wetlands	2.60	1.05	0.28
Evergreen Forest	0.30	0.12	0.03
Low Intensity Residential	1.10	0.45	0.12
Other Grasses (Urban, Rec., Parks)	1.70	0.69	0.18
Pasture/Hay	149.30	0.45	16.20
Row Crops	668.7	0.69	72.54
Woody Wetlands	30.4	60.45	3.30
TOTAL	**921.80**	**91.30**	**100.00**

TABLE 1.5 Blue Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	9.20	3.72	0.74
Emergent Herbaceous Wetlands	5.90	2.39	0.47
Pasture/Hay	27.90	11.30	2.23
Row Crops	1203.60	487.29	96.25
Woody Wetlands	3.90	1.58	0.31
TOTAL	**1250.50**	**506.28**	**100.00**

TABLE 1.6 Meyer/Cromwell Ditch Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	313.90	127.09	6.13
Emergent Herbaceous Wetlands	22.60	9.15	0.44
Evergreen Forest	1.70	0.69	0.03
High Intensity Residential	7.60	3.08	0.15
High Intensity Commercial/Industrial/Transport	12.10	4.90	0.24
Low Intensity Residential	39.20	15.87	0.77
Open Water	5.50	2.23	0.11
Other Grasses (Urban, Rec., Parks)	22.00	8.91	0.43
Pasture/Hay	495.60	200.65	9.68
Row Crops	4165.10	1686.28	81.37
Woody Wetlands	33.50	13.56	0.65
TOTAL	**5118.80**	**2072.39**	**100.00**

TABLE 1.7 Solomon Creek East Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	211.50	85.63	4.48
Emergent Herbaceous Wetlands	10.50	4.25	0.22
Evergreen Forest	0.20	0.08	0.00
High Intensity Residential	6.60	2.67	0.14
High Intensity Commercial/Industrial/Transport	23.80	9.64	0.50
Low Intensity Residential	23.30	9.43	0.49
Open Water	5.80	2.35	0.12
Pasture/Hay	422.20	170.93	8.94
Row Crops	3975.70	1609.60	84.21
Woody Wetlands	41.50	16.80	0.88
TOTAL	**4721.10**	**1911.38**	**100.00**

TABLE 1.8 Solomon Creek Headwaters Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	566.60	229.39	6.12
Emergent Herbaceous Wetlands	70.90	28.70	0.77
Evergreen Forest	0.40	0.16	0.00
High Intensity Residential	2.80	1.13	0.03
High Intensity Commercial/Industrial/Transport	1.00	0.40	0.01
Low Intensity Residential	8.30	3.36	0.09
Mixed Forest	0.20	0.08	0.00
Open Water	33.30	13.48	0.36
Pasture/Hay	894.90	362.31	9.67
Row Crops	7579.80	3068.74	81.89
Woody Wetlands	97.60	39.51	1.05
TOTAL	**9255.80**	**3747.29**	**100.00**

TABLE 1.9 Dry Run Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	79.00	31.98	2.86
Emergent Herbaceous Wetland	3.70	1.50	0.13
Low Intensity Residential	1.00	0.40	0.04
Open Water	2.20	0.89	0.08
Pasture/Hay	124.50	50.40	4.51
Row Crops	2478.00	1003.24	89.76
Woody Wetlands	72.30	29.27	2.62
TOTAL	**2760.70**	**1117.69**	**100.00**

TABLE 1.10 Mouths of Solomon Creek and Dry Run Subwatershed.

landcover	area (acres)	area (ha)	%
Deciduous Forest	140.80	57.00	5.16
Emergent Herbaceous Wetland	17.50	7.09	0.64
Evergreen Forest	1.50	0.61	0.05
High Intensity Commercial/Industrial/Transport	3.10	1.26	0.11
Low Intensity Residential	2.00	0.81	0.07
Open Water	0.20	0.08	0.01
Pasture/Hay	376.30	152.35	13.78
Row Crops	1984.90	803.60	72.70
Woody Wetlands	204.10	82.63	7.48
TOTAL	**2730.40**	**1105.43**	**100.00**

APPENDIX 2:

Structural and Managerial Conservation Practices

APPENDIX 2. Structural and managerial conservation practices that are relevant for use in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds. These conservation practices were adapted from the National Handbook of Conservation Practices. Their listing here does not imply endorsement by J.F. New & Associates, nor will every practice be relevant to every situation.

TABLE 2.1 Structural conservation practices that are relevant for use in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

Alley Cropping	Field Border	Sediment Basin
Access Road	Filter Strip	Stream Habitat Improvement and Management
Anionic Polyacrylamide (PAM) Erosion Control	Fish Passage	Streambank and Shoreline Protection
Animal Trails and Walkways	Floodwater Diversion	Structure for Water Control
Channel Vegetation	Floodway	Subsurface Drain
Clearing and Snagging	Grade Stabilization Structure	Surface Drainage, Field Ditch
Composting Facility	Grassed Waterway	Tree-Shrub Establishment
Conservation Cover	Grazing Land Mechanical Treatment	Tree/Shrub Pruning
Constructed Wetland	Heavy Use Area Protection	Underground Outlet
Contour Buffer Strips	Hedgerow Planting	Vegetative Buffers
Contour Farming	Herbaceous Wind Barriers	Waste Storage Facility
Controlled Drainage	Land Clearing	Waste Treatment Lagoon
Cover Crop	Lined Waterway or Outlet	Water and Sediment Control Basin
Critical Area Planting	Obstruction Removal	Water Table Control
Dam, Diversion	Open Channel	Wetland Creation
Dam, Floodwater Retarding	Pond	Wetland Enhancement
Dam, Mulitple Purpose	Range Planting	Wetland Restoration
Dike	Riparian Forest Buffer	Wildlife Watering Facility
Diversion	Riparian Herbaceous Cover	Windbreak/Shelterbelt Establishment
Fence	Rock Barrier	Windbreak/Shelterbelt Renovation

Source: National Handbook of Conservation Practices: **http://www.ncg.nrcs.usda.gov/nhcp_2.html**. Practice standards are available online at the above website or by contacting your county NRCS office.

TABLE 2.2 Managerial conservation practices that are relevant for use in the Whetten Ditch, Solomon Creek, and Dry Run Watersheds.

Bedding	Nutrient Management	Roof Runoff Management
Brush Management	Pasture and Hay Planting	Row Arrangement
Conservation Crop Rotation	Pest Management	Runoff Management System
Deep Tillage	Prescribed Burning	Shallow Water Management for Wildlife
Early Successional Habitat Development/Management	Prescribed Grazing	Stream Habitat Improvement and Management
Fishpond Management	Residue Management, Mulch Till	Stripcropping
Forage Harvest Management	Residue Management, No-Till and Strip Till	Upland Wildlife Habitat
Irrigation Water Management	Residue Management, Ridge Till	Waste Utilization
Manure Transfer	Residue Management, Seasonal	Water Table Control
Mulching	Restoration and Management of Declining Habitats	Wetland Wildlife Habitat Management

Source: National Handbook of Conservation Practices: **http://www.ncg.nrcs.usda.gov/nhcp_2.html**. Practice standards are available online at the above website or by contacting your county NRCS office.

APPENDIX 3:

Photos from the Riparian Management System Model in the Bear Creek Watershed, Iowa (Isenhart et al., 1997)

Bear Creek riparian management site from the Isenhart et al., 1997 study. Top photo shows site in March 1990, prior to buffer strip establishment. The bottom photo shows the same site in June 1994 after five growing seasons. Used with permission from the American Fisheries Society.

Wetland component of the Bear Creek riparian management system model from the Isenhart et al., 1997 study. Photo was taken in August 1994, a few months after construction. The water control structure can be seen in the foreground. Used with permission from the American Fisheries Society.

APPENDIX 4:

Endangered, Threatened, and Rare Species List,
Whetten Ditch, Solomon Creek, and Dry Run Watersheds

September 20, 2001

ENDANGERED, THREATENED, AND RARE SPECIES
AND HIGH QUALITY NATURAL COMMUNITIES AND NATURAL AREAS DOCUMENTED FROM
THE SOLOMON CREEK, DRY RUN AND WHETTON DITCH WATERSHEDS,
ELKHART, KOSCIUSKO AND NOBLE COUNTIES, INDIANA

Type.........	Element Name................	Common Name...............	State	Fed..	Townrang Sec	....	Date	Comments
LIGONIER QUADRANGLE								
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	034N008E	2 MI SE OF CROMWELL	1983	
Bird	ARDEA HERODIAS	GREAT BLUE HERON	**	**	034N008E 27	NWQ	1993	
Insect	EUPHYDRYAS PHAETON	BALTIMORE	**	**	034N008E 16		1930	
ENGLE LAKE MARSH SITE								
High Quality Community	WETLAND - MEADOW SEDGE	SEDGE MEADOW	SG	**	034N008E 02	NWQ	1979	
MERRIAM QUADRANGLE								
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	034N009E 033N009E 09	N OF BEAR LAKE	1997	
MILFORD QUADRANGLE								
High Quality Community	FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	003S006E 24	NEQ SWQ	1995	
Plant	GERANIUM ROBERTIANUM	HERB-ROBERT	ST	**	035N006E 28		1942	
RUCKSTUHL SITE								
Plant	LYCOPODIUM HICKEYI	HICKEY'S CLUBMOSS	SR	**	035N006E 23	SWQ SEQ	1979	
ORMAS QUADRANGLE								
Mammal	TAXIDEA TAXUS	AMERICAN BADGER	SE	**	034N009E 033N009E 09	N OF BEAR LAKE	1997	
PAUL THOMAS MEMORIAL BOG SITE								
High Quality Community	WETLAND - BOG ACID	ACID BOG	SG	**	033N008E 12	NEQ	1979	
High Quality Community	WETLAND - SWAMP SHRUB	SHRUB SWAMP	SG	**	033N008E 12	NEQ	1979	
Plant	ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	033N008E 12	CTR SH NEQ	1993	
Plant	VACCINIUM OXYCOCCOS	SMALL CRANBERRY	ST	**	033N008E 12	SH NEQ	1993	
MERRY LEA ENVIRONMENTAL CENTER (UNIV - GOSHEN COLLEGE)								
Plant	LYCOPODIUM HICKEYI	HICKEY'S CLUBMOSS	SR	**	033N009E 07	SWQ	1986	
Plant	LYCOPODIUM OBSCURUM	TREE CLUBMOSS	SR	**	033N009E 07	SWQ SWQ	1993	
MERRY LEA NATURE PRESERVE (UNIV- GOSHEN COLLEGE)								
Plant	CALLA PALUSTRIS	WILD CALLA	SE	**	033N008E 12		1938	

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant, SRE=state reintroduced

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

APPENDIX 5:

Endangered, Threatened, and Rare Species List,
Elkhart, Kosciusko, and Noble Counties

November 16, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM ELKHART COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ACTAEA RUBRA	RED BANEBERRY	SR	**	S2	G5
AMELANCHIER HUMILIS	RUNNING SERVICEBERRY	SE	**	S1	G5
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
ARABIS DRUMMONDII	DRUMMOND ROCKCRESS	SE	**	S1	G5
ARABIS MISSOURIENSIS VAR DEAMII	MISSOURI ROCKCRESS	SE	**	S1	G4?QT3?Q
ARENARIA STRICTA	MICHAUX'S STITCHWORT	SR	**	S2	G5
ASTER BOREALIS	RUSHLIKE ASTER	SR	**	S2	G5
BESSEYA BULLII	KITTEN TAILS	SE	**	S1	G3
CAREX BEBBII	BEBB'S SEDGE	ST	**	S2	G5
CAREX DEBILIS VAR RUDGEI	WHITE-EDGE SEDGE	ST	**	S2	G5T5
CAREX STRAMINEA	STRAW SEDGE	ST	**	S2	G5
CHIMAPHILA UMBELLATA SSP CISATLANTICA	PIPSISSEWA	ST	**	S2	G5T5
ELEOCHARIS EQUISETOIDES	HORSE-TAIL SPIKERUSH	SE	**	S1	G4
ELEOCHARIS ROBBINSII	ROBBINS SPIKERUSH	SR	**	S2	G4G5
ERIOCAULON AQUATICUM	PIPEWORT	SE	**	S1	G5
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
ERIOPHORUM VIRIDICARINATUM	GREEN-KEELED COTTON-GRASS	SR	**	S2	G5
FUIRENA PUMILA	DWARF UMBRELLA-SEDGE	ST	**	S2	G4
GERANIUM ROBERTIANUM	HERB-ROBERT	ST	**	S2	G5
GNAPHALIUM MACOUNII	WINGED CUDWEED	SX	**	SX	G5
ILIAMNA REMOTA	KANKAKEE GLOBE-MALLOW	SE	**	S1	G1Q
JUNIPERUS COMMUNIS	GROUND JUNIPER	SR	**	S2	G5
LYCOPODIUM HICKEYI	HICKEY'S CLUBMOSS	SR	**	S2	G5
LYCOPODIUM OBSCURUM	TREE CLUBMOSS	SR	**	S2	G5
MALAXIS UNIFOLIA	GREEN ADDER'S-MOUTH	SE	**	S1	G5
MATTEUCCIA STRUTHIOPTERIS	OSTRICH FERN	SR	**	S2	G5
MILIUM EFFUSUM	TALL MILLET-GRASS	SR	**	S2	G5
PINUS STROBUS	EASTERN WHITE PINE	SR	**	S2	G5
PLATANTHERA LEUCOPHAEA	PRAIRIE WHITE-FRINGED ORCHID	SE	LT	S1	G2
PLATANTHERA PSYCODES	SMALL PURPLE-FRINGE ORCHIS	SR	**	S2	G5
POA PALUDIGENA	BOG BLUEGRASS	WL	**	S3	G3
PSILOCARYA SCIRPOIDES	LONG-BEAKED BALDRUSH	ST	**	S2	G4
PYROLA ROTUNDIFOLIA VAR AMERICANA	AMERICAN WINTERGREEN	SR	**	S2	G5
QUERCUS PRINOIDES	DWARF CHINQUAPIN OAK	SE	**	S1	G5
RHYNCHOSPORA MACROSTACHYA	TALL BEAKED-RUSH	SR	**	S2	G4
SCIRPUS PURSHIANUS	WEAKSTALK BULRUSH	SE	**	S1	G4G5
SELAGINELLA RUPESTRIS	LEDGE SPIKE-MOSS	ST	**	S2	G5
SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	S2	G5
STIPA AVENACEA	BLACKSEED NEEDLEGRASS	ST	**	S2	G5
TOFIELDIA GLUTINOSA	FALSE ASPHODEL	SR	**	S2	G5
UTRICULARIA CORNUTA	HORNED BLADDERWORT	ST	**	S2	G5
UTRICULARIA MINOR	LESSER BLADDERWORT	SE	**	S1	G5

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FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM ELKHART COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
UTRICULARIA PURPUREA	PURPLE BLADDERWORT	SR	**	S2	G5
VACCINIUM OXYCOCCOS	SMALL CRANBERRY	ST	**	S2	G5
XYRIS DIFFORMIS	CAROLINA YELLOW-EYED GRASS	ST	**	S2	G5
MOLLUSCA: GASTROPODA					
CAMPELOMA DECISUM	POINTED CAMPELOMA	SSC	**	S2	G5
ARTHROPODA: INSECTA: ODONATA (DRAGONFLIES; DAMSELFLIES)					
SYMPETRUM SEMICINCTUM	BAND-WINGED MEADOWFLY	**	**	S2S3	G5
ARTHROPODA: INSECTA: COLEOPTERA (BEETLES)					
NICROPHORUS AMERICANUS	AMERICAN BURYING BEETLE	SX	LE	SH	G1
ARTHROPODA: INSECTA: TRICHOPTERA (CADDISFLIES)					
SETODES OLIGIUS	A CADDISFLY	SE	**	S1	G?
FISH					
MOXOSTOMA VALENCIENNESI	GREATER REDHORSE	SE	**	S2	G3
REPTILES					
CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	S2	G5
CLONOPHIS KIRTLANDII	KIRTLAND'S SNAKE	SE	**	S2	G2
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
MACROCLEMYS TEMMINCKII	ALLIGATOR SNAPPING TURTLE	SE	**	S1	G3G4
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
BIRDS					
ACCIPITER COOPERII	COOPER'S HAWK	**	**	S3B,SZN	G5
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
BARTRAMIA LONGICAUDA	UPLAND SANDPIPER	SE	**	S3B	G5
BOTAURUS LENTIGINOSUS	AMERICAN BITTERN	SE	**	S2B	G4
CIRCUS CYANEUS	NORTHERN HARRIER	SE	**	S2	G5
CISTOTHORUS PALUSTRIS	MARSH WREN	SE	**	S3B,SZN	G5
GRUS CANADENSIS	SANDHILL CRANE	SE	**	S2B,S1N	G5
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
LANIUS LUDOVICIANUS	LOGGERHEAD SHRIKE	SE	**	S3B,SZN	G5
RALLUS ELEGANS	KING RAIL	SE	**	S1B,SZN	G4G5
RALLUS LIMICOLA	VIRGINIA RAIL	SSC	**	S3B,SZN	G5
MAMMALS					
CONDYLURA CRISTATA	STAR-NOSED MOLE	SSC	**	S2?	G5
LYNX RUFUS	BOBCAT	SE	**	S1	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM ELKHART COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
HIGH QUALITY NATURAL COMMUNITY					
FOREST - FLOODPLAIN WET-MESIC	WET-MESIC FLOODPLAIN FOREST	SG	**	S3	G3?
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?
LAKE - LAKE	LAKE	SG	**	S2	
PRAIRIE - SAND DRY-MESIC	DRY-MESIC SAND PRAIRIE	SG	**	S3	G3
WETLAND - BEACH MARL	MARL BEACH	SG	**	S2	G3
WETLAND - BOG ACID	ACID BOG	SG	**	S2	G3
WETLAND - BOG CIRCUMNEUTRAL	CIRCUMNEUTRAL BOG	SG	**	S3	G3
WETLAND - FEN	FEN	SG	**	S3	G3
WETLAND - FLAT MUCK	MUCK FLAT	SG	**	S2	G2
WETLAND - FLAT SAND	SAND FLAT	SG	**	S1	G2
WETLAND - MARSH	MARSH	SG	**	S4	GU
WETLAND - SWAMP SHRUB	SHRUB SWAMP	SG	**	S2	GU

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern
FEDERAL: LE=endangered, LT=threatened, LELT=different listings for specific ranges of species, PE=proposed endangered, PT=proposed threatened, E/SA=appearance similar to LE species, **=not listed

November 12, 1999

ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ACTAEA RUBRA	RED BANEBERRY	SR	**	S2	G5
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
ARETHUSA BULBOSA	SWAMP-PINK	SX	**	SX	G4
ASTER BOREALIS	RUSHLIKE ASTER	SR	**	S2	G5
BIDENS BECKII	BECK WATER-MARIGOLD	SE	**	S1	G4G5T4
CAREX AUREA	GOLDEN-FRUITED SEDGE	SR	**	S2	G5
CAREX BEBBII	BEBB'S SEDGE	ST	**	S2	G5
CAREX CHORDORRHIZA	CREEPING SEDGE	SE	**	S1	G5
CAREX DISPERMA	SOFTLEAF SEDGE	SE	**	S1	G5
CAREX ECHINATA	LITTLE PRICKLY SEDGE	SE	**	S1	G5
CAREX FLAVA	YELLOW SEDGE	ST	**	S2	G5
CAREX PSEUDOCYPERUS	CYPERUS-LIKE SEDGE	SE	**	S1	G5
CORNUS AMOMUM SSP AMOMUM	SILKY DOGWOOD	SE	**	S1	G5T?
CORNUS CANADENSIS	BUNCHBERRY	SE	**	S1	G5
CYPRIPEDIUM CALCEOLUS VAR PARVIFLORUM	SMALL YELLOW LADY'S-SLIPPER	SR	**	S2	G5
CYPRIPEDIUM CANDIDUM	SMALL WHITE LADY'S-SLIPPER	SR	**	S2	G4
DROSERA INTERMEDIA	SPOON-LEAVED SUNDEW	SR	**	S2	G5
ELEOCHARIS GENICULATA	CAPITATE SPIKE-RUSH	ST	**	S2	G5
ERIOPHORUM ANGUSTIFOLIUM	NARROW-LEAVED COTTON-GRASS	SR	**	S2	G5
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
ERIOPHORUM VIRIDICARINATUM	GREEN-KEELED COTTON-GRASS	SR	**	S2	G5
GERANIUM ROBERTIANUM	HERB-ROBERT	ST	**	S2	G5
JUGLANS CINEREA	BUTTERNUT	WL	**	S3	G3G4
LATHYRUS OCHROLEUCUS	PALE VETCHLING PEAVINE	SE	**	S1	G4G5
LEMNA PERPUSILLA	MINUTE DUCKWEED	SX	**	SX	G5
MALAXIS UNIFOLIA	GREEN ADDER'S-MOUTH	SE	**	S1	G5
MATTEUCCIA STRUTHIOPTERIS	OSTRICH FERN	SR	**	S2	G5
MYRIOPHYLLUM VERTICILLATUM	WHORLED WATER-MILFOIL	ST	**	S2	G5
PANICUM BOREALE	NORTHERN WITCHGRASS	SR	**	S2	G5
PLATANTHERA PSYCODES	SMALL PURPLE-FRINGE ORCHIS	SR	**	S2	G5
POTAMOGETON EPIHYDRUS	NUTTALL PONDWEED	SE	**	S1	G5
POTAMOGETON FRIESII	FRIES' PONDWEED	SE	**	S1	G4
POTAMOGETON OAKESIANUS	OAKES PONDWEED	SE	**	S1	G4
POTAMOGETON RICHARDSONII	REDHEADGRASS	ST	**	S2	G5
POTAMOGETON STRICTIFOLIUS	STRAIGHT-LEAF PONDWEED	SE	**	S1	G5
PRUNUS PENSYLVANICA	FIRE CHERRY	SR	**	S2	G5
SCIRPUS SUBTERMINALIS	WATER BULRUSH	SR	**	S2	G4G5
SELAGINELLA APODA	MEADOW SPIKE-MOSS	SE	**	S1	G5
SPARGANIUM ANDROCLADUM	BRANCHING BUR-REED	ST	**	S2	G4G5
SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	S2	G5
STENANTHIUM GRAMINEUM	EASTERN FEATHERBELLS	SE	**	S1	G4G5
TOFIELDIA GLUTINOSA	FALSE ASPHODEL	SR	**	S2	G5

STATE: SX=extirpated, SE=endangered, ST=threatened, SR=rare, SSC=special concern, WL=watch list, SG=significant,** no status but rarity warrants concern

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ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM KOSCIUSKO COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
UTRICULARIA RESUPINATA	NORTHEASTERN BLADDERWORT	SX	**	SX	G4
VACCINIUM OXYCOCCOS	SMALL CRANBERRY	ST	**	S2	G5
WOLFFIELLA FLORIDANA	SWORD BOGMAT	SX	**	SX	G5
ZANNICHELLIA PALUSTRIS	HORNED PONDWEED	SE	**	S1	G5
ZIGADENUS ELEGANS VAR GLAUCUS	WHITE CAMAS	SR	**	S2	G5T4T5
MOLLUSCA: BIVALVIA (MUSSELS)					
ALASMIDONTA VIRIDIS	SLIPPERSHELL MUSSEL	**	**	S2	G4G5
EPIOBLASMA OBLIQUATA PEROBLIQUA	WHITE CAT'S PAW PEARLYMUSSEL	SE	LE	S1	G1T1
EPIOBLASMA TORULOSA RANGIANA	NORTHERN RIFFLESHELL	SE	LE	S1	G2T2
LAMPSILIS FASCIOLA	WAVY-RAYED LAMPMUSSEL	SSC	**	S2	G4
LAMPSILIS OVATA	POCKETBOOK	**	**	S2	G5
LIGUMIA RECTA	BLACK SANDSHELL	**	**	S2	G5
PLEUROBEMA CLAVA	CLUBSHELL	SE	LE	S1	G2
PTYCHOBRANCHUS FASCIOLARIS	KIDNEYSHELL	SSC	**	S2	G4G5
QUADRULA CYLINDRICA CYLINDRICA	RABBITSFOOT	SE	**	S1	G3T3
TOXOLASMA LIVIDUS	PURPLE LILLIPUT	SSC	**	S2	G2
TOXOLASMA PARVUM	LILLIPUT	**	**	S2	G5
VILLOSA FABALIS	RAYED BEAN	SSC	**	S1	G1G2
VILLOSA LIENOSA	LITTLE SPECTACLECASE	SSC	**	S2	G5
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					
EUPHYDRYAS PHAETON	BALTIMORE	**	**	S2S4	G4
EUPHYES BIMACULA	TWO-SPOTTED SKIPPER	SR	**	S2	G4
EURISTRYMON ONTARIO	NORTHERN HAIRSTREAK	WL	**	S2S4	G4
HESPERIA LEONARDUS	LEONARDUS SKIPPER	SR	**	S2	G4
LYCAENA HELLOIDES	PURPLISH COPPER	**	**	S2S4	G5
PIERIS OLERACEA	VEINED WHITE	SE	**	S1	G5T4
ARTHROPODA: INSECTA: LEPIDOPTERA (MOTHS)					
HEMILEUCA SP 3	MIDWESTERN FEN BUCKMOTH	**	**	S1?	G3G4
LYTROSIS PERMAGNARIA	A LYTROSIS MOTH	ST	**	S2	GU
FISH					
ACIPENSER FULVESCENS	LAKE STURGEON	SE	**	S1	G3
COREGONUS ARTEDI	CISCO	SSC	**	S2	G5
HYBOPSIS AMBLOPS	BIGEYE CHUB	**	**	S2	G5
NOTROPIS HETEROLEPIS	BLACKNOSE SHINER	**	**	S2	G5
PERCINA EVIDES	GILT DARTER	SE	**	S1	G4
AMPHIBIANS					
AMBYSTOMA LATERALE	BLUE-SPOTTED SALAMANDER	SSC	**	S2	G5
HEMIDACTYLIUM SCUTATUM	FOUR-TOED SALAMANDER	SE	**	S2	G5

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SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
NECTURUS MACULOSUS	MUDPUPPY	SSC	**	S2	G5
RANA PIPIENS	NORTHERN LEOPARD FROG	SSC	**	S2	G5
REPTILES					
CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	S2	G5
CLONOPHIS KIRTLANDII	KIRTLAND'S SNAKE	SE	**	S2	G2
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
NERODIA ERYTHROGASTER NEGLECTA	COPPERBELLY WATER SNAKE	SE	**	S2	G5T2T3
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
BIRDS					
ACCIPITER COOPERII	COOPER'S HAWK	**	**	S3B,SZN	G5
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
BOTAURUS LENTIGINOSUS	AMERICAN BITTERN	SE	**	S2B	G4
CHLIDONIAS NIGER	BLACK TERN	SE	**	S1B,SZN	G4
CIRCUS CYANEUS	NORTHERN HARRIER	SE	**	S2	G5
CISTOTHORUS PALUSTRIS	MARSH WREN	SE	**	S3B,SZN	G5
CISTOTHORUS PLATENSIS	SEDGE WREN	SE	**	S3B,SZN	G5
DENDROICA CERULEA	CERULEAN WARBLER	SSC	**	S3B	G4
FALCO PEREGRINUS	PEREGRINE FALCON	SE	E(S/A)	S2B,SZN	G4
GRUS CANADENSIS	SANDHILL CRANE	SE	**	S2B,S1N	G5
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
MNIOTILTA VARIA	BLACK-AND-WHITE WARBLER	SSC	**	S1S2B	G5
NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	S1B,SAN	G5
RALLUS ELEGANS	KING RAIL	SE	**	S1B,SZN	G4G5
RALLUS LIMICOLA	VIRGINIA RAIL	SSC	**	S3B,SZN	G5
VERMIVORA CHRYSOPTERA	GOLDEN-WINGED WARBLER	SE	**	S1B	G4
MAMMALS					
CONDYLURA CRISTATA	STAR-NOSED MOLE	SSC	**	S2?	G5
LUTRA CANADENSIS	NORTHERN RIVER OTTER	SE	**	S?	G5
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
MYOTIS SODALIS	INDIANA BAT OR SOCIAL MYOTIS	SE	LE	S1	G2
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	S4	G4
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?
LAKE - LAKE	LAKE	SG	**	S2	
WETLAND - BEACH MARL	MARL BEACH	SG	**	S2	G3
WETLAND - BOG ACID	ACID BOG	SG	**	S2	G3
WETLAND - BOG CIRCUMNEUTRAL	CIRCUMNEUTRAL BOG	SG	**	S3	G3
WETLAND - FEN	FEN	SG	**	S3	G3

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SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
WETLAND - FEN FORESTED	FORESTED FEN	SG	**	S1	G3
WETLAND - MARSH	MARSH	SG	**	S4	GU
WETLAND - MEADOW SEDGE	SEDGE MEADOW	SG	**	S1	G3?
WETLAND - SWAMP SHRUB	SHRUB SWAMP	SG	**	S2	GU

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November 16, 1999

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SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VASCULAR PLANT					
ACTAEA RUBRA	RED BANEBERRY	SR	**	S2	G5
ANDROMEDA GLAUCOPHYLLA	BOG ROSEMARY	SR	**	S2	G5
ARALIA HISPIDA	BRISTLY SARSAPARILLA	SE	**	S1	G5
ARISTIDA INTERMEDIA	SLIM-SPIKE THREE-AWN GRASS	SR	**	S2	G?
ASTER BOREALIS	RUSHLIKE ASTER	SR	**	S2	G5
CALLA PALUSTRIS	WILD CALLA	SE	**	S1	G5
CAREX BEBBII	BEBB'S SEDGE	ST	**	S2	G5
CRATAEGUS PRONA	ILLINOIS HAWTHORN	SE	**	S1	G4G5
CYPRIPEDIUM CANDIDUM	SMALL WHITE LADY'S-SLIPPER	SR	**	S2	G4
DROSERA INTERMEDIA	SPOON-LEAVED SUNDEW	SR	**	S2	G5
DRYOPTERIS CLINTONIANA	CLINTON WOODFERN	SX	**	SX	G5
ERIOPHORUM GRACILE	SLENDER COTTON-GRASS	ST	**	S2	G5
ERIOPHORUM VIRIDICARINATUM	GREEN-KEELED COTTON-GRASS	SR	**	S2	G5
GENTIANA ALBA	YELLOW GENTIAN	SR	**	S2	G4
GERANIUM BICKNELLII	BICKNELL NORTHERN CRANE'S-BILL	SE	**	S1	G5
GEUM RIVALE	PURPLE AVENS	SE	**	S1	G5
HYPERICUM PYRAMIDATUM	GREAT ST. JOHN'S-WORT	SE	**	S1	G4
LATHYRUS OCHROLEUCUS	PALE VETCHLING PEAVINE	SE	**	S1	G4G5
LATHYRUS VENOSUS	SMOOTH VEINY PEA	ST	**	S2	G5
LEMNA PERPUSILLA	MINUTE DUCKWEED	SX	**	SX	G5
LINNAEA BOREALIS	TWINFLOWER	SX	**	SX	G5
LYCOPODIUM HICKEYI	HICKEY'S CLUBMOSS	SR	**	S2	G5
LYCOPODIUM OBSCURUM	TREE CLUBMOSS	SR	**	S2	G5
MALAXIS UNIFOLIA	GREEN ADDER'S-MOUTH	SE	**	S1	G5
MATTEUCCIA STRUTHIOPTERIS	OSTRICH FERN	SR	**	S2	G5
MILIUM EFFUSUM	TALL MILLET-GRASS	SR	**	S2	G5
PANICUM LEIBERGII	LEIBERG'S WITCHGRASS	ST	**	S2	G5
PLATANTHERA CILIARIS	YELLOW-FRINGE ORCHIS	SE	**	S1	G5
PLATANTHERA LEUCOPHAEA	PRAIRIE WHITE-FRINGED ORCHID	SE	LT	S1	G2
PLATANTHERA ORBICULATA	LARGE ROUNDLEAF ORCHID	SX	**	SX	G5?
PLATANTHERA PSYCODES	SMALL PURPLE-FRINGE ORCHIS	SR	**	S2	G5
PRUNUS PENSYLVANICA	FIRE CHERRY	SR	**	S2	G5
PYROLA ROTUNDIFOLIA VAR AMERICANA	AMERICAN WINTERGREEN	SR	**	S2	G5
SALIX SERISSIMA	AUTUMN WILLOW	ST	**	S2	G4
SCHEUCHZERIA PALUSTRIS SSP AMERICANA	AMERICAN SCHEUCHZERIA	SE	**	S1	G5T5
SPIRANTHES LUCIDA	SHINING LADIES'-TRESSES	SR	**	S2	G5
SPIRANTHES ROMANZOFFIANA	HOODED LADIES'-TRESSES	SE	**	S1	G5
STIPA COMATA	SEWING NEEDLEGRASS	SX	**	SX	G5
TOFIELDIA GLUTINOSA	FALSE ASPHODEL	SR	**	S2	G5
TRIGLOCHIN PALUSTRE	MARSH ARROW-GRASS	ST	**	S2	G5
UTRICULARIA CORNUTA	HORNED BLADDERWORT	ST	**	S2	G5
UTRICULARIA RESUPINATA	NORTHEASTERN BLADDERWORT	SX	**	SX	G4

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SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
VACCINIUM OXYCOCCOS	SMALL CRANBERRY	ST	**	S2	G5
VIBURNUM CASSINOIDES	NORTHERN WILD-RAISIN	SE	**	S1	G5
ZIGADENUS ELEGANS VAR GLAUCUS	WHITE CAMAS	SR	**	S2	G5T4T5
ARTHROPODA: INSECTA: LEPIDOPTERA (BUTTERFLIES; SKIPPERS)					
EUPHYDRYAS PHAETON	BALTIMORE	**	**	S2S4	G4
LYCAENA DORCAS DORCAS	DORCAS COPPER	**	**	S2	G4TU
PIERIS OLERACEA	VEINED WHITE	SE	**	S1	G5T4
FISH					
COREGONUS ARTEDI	CISCO	SSC	**	S2	G5
AMPHIBIANS					
AMBYSTOMA LATERALE	BLUE-SPOTTED SALAMANDER	SSC	**	S2	G5
NECTURUS MACULOSUS	MUDPUPPY	SSC	**	S2	G5
REPTILES					
CLEMMYS GUTTATA	SPOTTED TURTLE	SE	**	S2	G5
EMYDOIDEA BLANDINGII	BLANDING'S TURTLE	SE	**	S2	G4
SISTRURUS CATENATUS CATENATUS	EASTERN MASSASAUGA	SE	**	S2	G3G4T3T4
THAMNOPHIS BUTLERI	BUTLER'S GARTER SNAKE	SE	**	S1	G4
BIRDS					
ACCIPITER COOPERII	COOPER'S HAWK	**	**	S3B,SZN	G5
AMMODRAMUS HENSLOWII	HENSLOW'S SPARROW	SE	**	S3B,SZN	G4
ARDEA HERODIAS	GREAT BLUE HERON	**	**	S4B,SZN	G5
AYTHYA COLLARIS	RING-NECKED DUCK	**	**	SHB,SZN	G5
BUTEO LINEATUS	RED-SHOULDERED HAWK	SSC	**	S3	G5
CHLIDONIAS NIGER	BLACK TERN	SE	**	S1B,SZN	G4
DENDROICA CERULEA	CERULEAN WARBLER	SSC	**	S3B	G4
IXOBRYCHUS EXILIS	LEAST BITTERN	SE	**	S3B	G5
NYCTICORAX NYCTICORAX	BLACK-CROWNED NIGHT-HERON	SE	**	S1B,SAN	G5
TYTO ALBA	BARN OWL	SE	**	S2	G5
MAMMALS					
CONDYLURA CRISTATA	STAR-NOSED MOLE	SSC	**	S2?	G5
LUTRA CANADENSIS	NORTHERN RIVER OTTER	SE	**	S?	G5
LYNX RUFUS	BOBCAT	SE	**	S1	G5
MUSTELA NIVALIS	LEAST WEASEL	SSC	**	S2?	G5
TAXIDEA TAXUS	AMERICAN BADGER	SE	**	S2	G5
HIGH QUALITY NATURAL COMMUNITY					
FOREST - FLOODPLAIN WET	WET FLOODPLAIN FOREST	SG	**	S3	G3?

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ENDANGERED, THREATENED AND RARE SPECIES DOCUMENTED FROM NOBLE COUNTY, INDIANA

SPECIES NAME	COMMON NAME	STATE	FED	SRANK	GRANK
FOREST - FLOODPLAIN WET-MESIC	WET-MESIC FLOODPLAIN FOREST	SG	**	S3	G3?
FOREST - UPLAND DRY-MESIC	DRY-MESIC UPLAND FOREST	SG	**	S4	G4
FOREST - UPLAND MESIC	MESIC UPLAND FOREST	SG	**	S3	G3?
LAKE - LAKE	LAKE	SG	**	S2	
LAKE - POND	POND	SG	**	S?	
WETLAND - BEACH MARL	MARL BEACH	SG	**	S2	G3
WETLAND - BOG ACID	ACID BOG	SG	**	S2	G3
WETLAND - BOG CIRCUMNEUTRAL	CIRCUMNEUTRAL BOG	SG	**	S3	G3
WETLAND - FEN	FEN	SG	**	S3	G3
WETLAND - FEN FORESTED	FORESTED FEN	SG	**	S1	G3
WETLAND - MARSH	MARSH	SG	**	S4	GU
WETLAND - MEADOW SEDGE	SEDGE MEADOW	SG	**	S1	G3?
WETLAND - SWAMP FOREST	FORESTED SWAMP	SG	**	S2	G2?
WETLAND - SWAMP SHRUB	SHRUB SWAMP	SG	**	S2	GU

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APPENDIX 6:

Stream Sampling Laboratory Datasheets

SAMPLE RESULTS

CLIENT SAMPLE ID: # 1
CLIENT PROJECT: Surface Water
SAMPLE TYPE: Water(Non DW)
Date Sampled: 5/16/01

Report Date: 6/1/01
EIS Sample No: 075553
EIS Order No: 010500153
Date Received: 5/16/01

Parameter	Results	Units	RDL	MDL	Analyst	Test Date	Method
Coliform,E.Coli *	1900	col/100ml	0	0	ClarkS	5/16/01	40CFR141
Dissolved Oxygen	7.2	mg/L	0.5	0.5	LozanoS	5/16/01	4500-O C
Nitrogen(Kjeldahl)Total *	1.8	mg/L	0.1	0.1	SzkarlatM	5/23/01	4500-N B
Nitrogen(Ammonia) *	0.25	mg/L	0.05	0.05	SzkarlatM	5/17/01	4500-NH3
Nitrogen(Nitrate+Nitrite) *	7.0	mg/L	0.1	0.1	SzkarlatM	5/16/01	4500-NO3
pH	7.2	SU			LozanoS	5/16/01	4500-H B
Phosphorus,ortho *	0.06	mg/L	0.05	0.05	SzkarlatM	5/18/01	4500-P F
Phosphorus,Total *	0.43	mg/L	0.05	0.05	SzkarlatM	5/23/01	4500-P F
Solids,Total Suspended *	91	mg/L	1	1	LozanoS	5/18/01	2540 D
Specific Conductance	320	umhos/cm	1	1	ClarkS	5/17/01	120.1
Turbidity	190	NTU	1	1	ShaneD	5/23/01	180.1

SAMPLE RESULTS

CLIENT SAMPLE ID: **# 2**
CLIENT PROJECT: **Surface Water**
SAMPLE TYPE: **Water(Non DW)**
Date Sampled: 5/16/01

Report Date: 6/1/01
EIS Sample No: 075554
EIS Order No: 010500153
Date Received: 5/16/01

Parameter	Results	Units	RDL	MDL	Analyst	Test Date	Method
Coliform,E.Coli	900	col/100ml	0	0	ClarkS	5/16/01	40CFR141
Dissolved Oxygen	7.4	mg/L	0.5	0.5	LozanoS	5/16/01	4500-O C
Nitrogen(Kjeldahl)Total	0.86	mg/L	0.1	0.1	SzkarlatM	5/23/01	4500-N B
Nitrogen(Ammonia)	0.09	mg/L	0.05	0.05	SzkarlatM	5/17/01	4500-NH3
Nitrogen(Nitrate+Nitrite)	5.8	mg/L	0.1	0.1	SzkarlatM	5/16/01	4500-NO3
pH	7.4	SU			LozanoS	5/16/01	4500-H B
Phosphorus,ortho	<0.05	mg/L	0.05	0.05	SzkarlatM	5/18/01	4500-P F
Phosphorus,Total	0.15	mg/L	0.05	0.05	SzkarlatM	5/23/01	4500-P F
Solids,Total Suspended	35	mg/L	1	1	LozanoS	5/18/01	2540 D
Specific Conductance	580	umhos/cm	1	1	ClarkS	5/17/01	120.1
Turbidity	54	NTU	1	1	ShaneD	5/23/01	180.1

SAMPLE RESULTS

CLIENT SAMPLE ID: # 3
CLIENT PROJECT: Surface Water
SAMPLE TYPE: Water(Non DW)
Date Sampled: 5/16/01

Report Date: 6/1/01
EIS Sample No: 075555
EIS Order No: 010500153
Date Received: 5/16/01

Parameter	Results	Units	RDL	MDL	Analyst	Test Date	Method
Coliform,E.Coli	900	col/100ml	0	0	ClarkS	5/16/01	40CFR141
Dissolved Oxygen	7.35	mg/L	0.5	0.5	LozanoS	5/16/01	4500-O C
Nitrogen(Kjeldahl)Total	0.26	mg/L	0.1	0.1	SzkarlatM	5/23/01	4500-N B
Nitrogen(Ammonia)	<0.05	mg/L	0.05	0.05	SzkarlatM	5/17/01	4500-NH3
Nitrogen(Nitrate+Nitrite)	6.9	mg/L	0.1	0.1	SzkarlatM	5/16/01	4500-NO3
pH	7.5	SU			LozanoS	5/16/01	4500-H B
Phosphorus,ortho	<0.05	mg/L	0.05	0.05	SzkarlatM	5/18/01	4500-P F
Phosphorus,Total	0.12	mg/L	0.05	0.05	SzkarlatM	5/23/01	4500-P F
Solids,Total Suspended	10	mg/L	1	1	LozanoS	5/18/01	2540 D
Specific Conductance	550	umhos/cm	1	1	ClarkS	5/17/01	120.1
Turbidity	17	NTU	1	1	ShaneD	5/23/01	180.1

SAMPLE RESULTS

CLIENT SAMPLE ID: **# 4**
CLIENT PROJECT: **Surface Water**
SAMPLE TYPE: **Water(Non DW)**
Date Sampled: 5/16/01

Report Date: 6/1/01
EIS Sample No: 075556
EIS Order No: 010500153
Date Received: 5/16/01

Parameter	Results	Units	RDL	MDL	Analyst	Test Date	Method
Coliform,E.Coli	5700	col/100ml	0	0	ClarkS	5/16/01	40CFR141
Dissolved Oxygen	6.4	mg/L	0.5	0.5	LozanoS	5/16/01	4500-O C
Nitrogen(Kjeldahl)Total	2.9	mg/L	0.1	0.1	SzkarlatM	5/23/01	4500-N B
Nitrogen(Ammonia)	0.77	mg/L	0.05	0.05	SzkarlatM	5/17/01	4500-NH3
Nitrogen(Nitrate+Nitrite)	5.9	mg/L	0.1	0.1	SzkarlatM	5/16/01	4500-NO3
pH	7.3	SU			LozanoS	5/16/01	4500-H B
Phosphorus,ortho	0.06	mg/L	0.05	0.05	SzkarlatM	5/18/01	4500-P F
Phosphorus,Total	0.51	mg/L	0.05	0.05	SzkarlatM	5/23/01	4500-P F
Solids,Total Suspended	75	mg/L	1	1	LozanoS	5/18/01	2540 D
Specific Conductance	330	umhos/cm	1	1	ClarkS	5/17/01	120.1
Turbidity	290	NTU	1	1	ShaneD	5/23/01	180.1

SAMPLE RESULTS

CLIENT SAMPLE ID: # 5
CLIENT PROJECT: Surface Water
SAMPLE TYPE: Water(Non DW)
Date Sampled: 5/16/01

Report Date: 6/1/01
EIS Sample No: 075557
EIS Order No: 010500153
Date Received: 5/16/01

Parameter	Results	Units	RDL	MDL	Analyst	Test Date	Method
Coliform,E.Coli	230	col/100ml	0	0	ClarkS	5/16/01	40CFR141
Dissolved Oxygen	6.9	mg/L	0.5	0.5	LozanoS	5/16/01	4500-O C
Nitrogen(Kjeldahl)Total	0.36	mg/L	0.1	0.1	SzkarlatM	5/23/01	4500-N B
Nitrogen(Ammonia)	0.16	mg/L	0.05	0.05	SzkarlatM	5/17/01	4500-NH3
Nitrogen(Nitrate+Nitrite)	6.5	mg/L	0.1	0.1	SzkarlatM	5/16/01	4500-NO3
pH	7.4	SU			LozanoS	5/16/01	4500-H B
Phosphorus,ortho	<0.05	mg/L	0.05	0.05	SzkarlatM	5/18/01	4500-P F
Phosphorus,Total	0.14	mg/L	0.05	0.05	SzkarlatM	5/23/01	4500-P F
Solids,Total Suspended	21	mg/L	1	1	LozanoS	5/18/01	2540 D
Specific Conductance	710	umhos/cm	1	1	ClarkS	5/17/01	120.1
Turbidity	21	NTU	1	1	ShaneD	5/23/01	180.1

SAMPLE RESULTS

CLIENT SAMPLE ID: # 6
CLIENT PROJECT: Surface Water
SAMPLE TYPE: Water(Non DW)
Date Sampled: 5/16/01

Report Date: 6/1/01
EIS Sample No: 075558
EIS Order No: 010500153
Date Received: 5/16/01

Parameter	Results	Units	RDL	MDL	Analyst	Test Date	Method
Coliform,E.Coli	460	col/100ml	0	0	ClarkS	5/16/01	40CFR141
Dissolved Oxygen	7.0	mg/L	0.5	0.5	LozanoS	5/16/01	4500-O C
Nitrogen(Kjeldahl)Total	0.58	mg/L	0.1	0.1	SzkarlatM	5/23/01	4500-N B
Nitrogen(Ammonia)	<0.05	mg/L	0.05	0.05	SzkarlatM	5/17/01	4500-NH3
Nitrogen(Nitrate+Nitrite)	5.0	mg/L	0.1	0.1	SzkarlatM	5/16/01	4500-NO3
pH	7.6	SU			LozanoS	5/16/01	4500-H B
Phosphorus,ortho	<0.05	mg/L	0.05	0.05	SzkarlatM	5/18/01	4500-P F
Phosphorus,Total	0.17	mg/L	0.05	0.05	SzkarlatM	5/23/01	4500-P F
Solids,Total Suspended	11	mg/L	1	1	LozanoS	5/18/01	2540 D
Specific Conductance	640	umhos/cm	1	1	ClarkS	5/17/01	120.1
Turbidity	17	NTU	1	1	ShaneD	5/23/01	180.1

SAMPLE RESULTS

CLIENT SAMPLE ID: # 7
CLIENT PROJECT: Surface Water
SAMPLE TYPE: Water(Non DW)
Date Sampled: 5/16/01

Report Date: 6/1/01
EIS Sample No: 075559
EIS Order No: 010500153
Date Received: 5/16/01

Parameter	Results	Units	RDL	MDL	Analyst	Test Date	Method
Coliform,E.Coli	180	col/100ml	0	0	ClarkS	5/16/01	40CFR141
Dissolved Oxygen	6.55	mg/L	0.5	0.5	LozanoS	5/16/01	4500-O C
Nitrogen(Kjeldahl)Total	0.71	mg/L	0.1	0.1	SzkarlatM	5/23/01	4500-N B
Nitrogen(Ammonia)	0.15	mg/L	0.05	0.05	SzkarlatM	5/17/01	4500-NH3
Nitrogen(Nitrate+Nitrite)	1.9	mg/L	0.1	0.1	SzkarlatM	5/16/01	4500-NO3
pH	7.7	SU			LozanoS	5/16/01	4500-H B
Phosphorus,ortho	<0.05	mg/L	0.05	0.05	SzkarlatM	5/18/01	4500-P F
Phosphorus,Total	0.14	mg/L	0.05	0.05	SzkarlatM	5/23/01	4500-P F
Solids,Total Suspended	28	mg/L	4	1	LozanoS	5/18/01	2540 D
Specific Conductance	1950	umhos/cm	1	1	ClarkS	5/17/01	120.1
Turbidity	13	NTU	1	1	ShaneD	5/23/01	180.1

SAMPLE RESULTS

CLIENT SAMPLE ID: **# 8**
CLIENT PROJECT: **Surface Water**
SAMPLE TYPE: **Water(Non DW)**
Date Sampled: 5/16/01

Report Date: 6/1/01
EIS Sample No: 075560
EIS Order No: 010500153
Date Received: 5/16/01

Parameter	Results	Units	RDL	MDL	Analyst	Test Date	Method
Coliform,E.Coli	154	col/100ml	0	0	ClarkS	5/16/01	40CFR141
Dissolved Oxygen	6.5	mg/L	0.5	0.5	LozanoS	5/16/01	4500-O C
Nitrogen(Kjeldahl)Total	0.87	mg/L	0.1	0.1	SzkarlatM	5/23/01	4500-N B
Nitrogen(Ammonia)	<0.05	mg/L	0.05	0.05	SzkarlatM	5/17/01	4500-NH3
Nitrogen(Nitrate+Nitrite)	1.3	mg/L	0.1	0.1	SzkarlatM	5/16/01	4500-NO3
pH	7.6	SU			LozanoS	5/16/01	4500-H B
Phosphorus,ortho	<0.05	mg/L	0.05	0.05	SzkarlatM	5/18/01	4500-P F
Phosphorus,Total	0.12	mg/L	0.05	0.05	SzkarlatM	5/23/01	4500-P F
Solids,Total Suspended	3	mg/L	1	1	LozanoS	5/18/01	2540 D
Specific Conductance	630	umhos/cm	1	1	ClarkS	5/17/01	120.1
Turbidity	4.8	NTU	1	1	ShaneD	5/23/01	180.1

SAMPLE RESULTS

Client Name: J.F. New & Associates
Client Project: Elkhart Co.

Report Date: 6/22/01
EIS Order No: **010600045**

EIS Lab Number	Client Description	Sample Date	Parameter	Result	Units	RDL	Test Date	Analyst	Method
075950	Site 9	6/6/01	Coliform,E.Coli	790	col/100ml	0	6/6/01	ClarkS	40CFR141
		6/6/01	Dissolved Oxygen	8.0	mg/L	0.5	6/6/01	NyeD	4500-O G
		6/6/01	Nitrogen(Kjeldahl)Total	<0.1	mg/L	0.1	6/8/01	SzkarlatM	4500-N B
		6/6/01	Nitrogen(Ammonia)	<0.05	mg/L	0.05	6/8/01	SzkarlatM	4500-NH3
		6/6/01	Nitrogen(Nitrate+Nitrite)	18	mg/L	0.1	6/6/01	SzkarlatM	4500-NO3
		6/6/01	pH	7.6	SU		6/6/01	LozanoS	4500-H B
		6/6/01	Phosphorus,ortho	0.12	mg/L	0.05	6/8/01	SzkarlatM	4500-P F
		6/6/01	Phosphorus,Total	0.12	mg/L	0.05	6/8/01	SzkarlatM	4500-P F
		6/6/01	Solids,Total Suspended	1	mg/L	1	6/7/01	LozanoS	2540 D
		6/6/01	Specific Conductance	500	umhos/cm	1	6/13/01	LozanoS	120.1
		6/6/01	Turbidity	10.8	NTU	1	6/20/01	ShaneD	180.1

SAMPLE RESULTS

Client Name: J.F. New & Associates
Client Project: Elkhart Co.

Report Date: 7/12/01
EIS Order No: 010600266

EIS Lab Number	Client Description	Sample Date	Parameter	Result	Units	RDL	Test Date	Analyst	Method
076420	1	6/27/01	Coliform,E.Coli	400	col/100ml	0	6/27/01	ClarkS	40CFR141
076421	2	6/27/01	Coliform,E.Coli	200	col/100ml	0	6/27/01	ClarkS	40CFR141
076422	2 Dup.	6/27/01	Coliform,E.Coli	200	col/100ml	0	6/27/01	ClarkS	40CFR141
076423	3	6/27/01	Coliform,E.Coli	<100	col/100ml	0	6/27/01	ClarkS	40CFR141
076424	4	6/27/01	Coliform,E.Coli	200	col/100ml	0	6/27/01	ClarkS	40CFR141
076425	5	6/27/01	Coliform,E.Coli	100	col/100ml	0	6/27/01	ClarkS	40CFR141
076426	6	6/27/01	Coliform,E.Coli	200	col/100ml	0	6/27/01	ClarkS	40CFR141
076427	7	6/27/01	Coliform,E.Coli	100	col/100ml	0	6/27/01	ClarkS	40CFR141
076428	8	6/27/01	Coliform,E.Coli	<100	col/100ml	0	6/27/01	ClarkS	40CFR141
076429	9	6/27/01	Coliform,E.Coli	700	col/100ml	0	6/27/01	ClarkS	40CFR141
076430	10	6/27/01	Coliform,E.Coli	<100	col/100ml	0	6/27/01	ClarkS	40CFR141

APPENDIX 7:

QHEI Datasheet

STREAM: ______________ **RIVER MILE:** __________ **DATE:** __________ **QHEI SCORE** ☐

1) SUBSTRATE: (Check ONLY Two Substrate Type Boxes: Check all types present) **SUBSTRATE SCORE** ☐

TYPE		POOL	RIFFLE		POOL	RIFFLE
☐ ☐	BLDER/SLAB(10)	___	___	☐ ☐ GRAVEL(7)	___	___
☐ ☐	BOULDER(9)	___	___	☐ ☐ SAND(6)	___	___
☐ ☐	COBBLE(8)	___	___	☐ ☐ BEDROCK(5)	___	___
☐ ☐	HARDPAN(4)	___	___	☐ ☐ DETRITUS(3)	___	___
☐ ☐	MUCK/SILT(2)	___	___	☐ ☐ ARTIFIC(0)	___	___

SUBSTRATE ORIGIN (all)
- ☐ LIMESTONE(1) ☐ RIP/RAP(0)
- ☐ TILLS(1) ☐ HARDPAN(0)
- ☐ SANDSTONE(0)
- ☐ SHALE(-1)
- ☐ COAL FINES(-2)

SILT COVER (one)
- ☐ SILT-HEAVY(-2) ☐ SILT-MOD(-1)
- ☐ SILT-NORM(0) ☐ SILT-FREE(1)

Extent of Embeddedness (check one)
- ☐ EXTENSIVE(-2) ☐ MODERATE(-1)
- ☐ LOW(0) ☐ NONE(1)

TOTAL NUMBER OF SUBSTRATE TYPES: ☐ >4(2) ☐ <4(0)

NOTE: (Ignore sludge that originates from point sources: score is based on natural substrates)

COMMENTS: ______________

2) INSTREAM COVER: **COVER SCORE** ☐

TYPE (Check all that apply)
- ☐ UNDERCUT BANKS(1) ☐ DEEP POOLS(2) ☐ OXBOWS(1)
- ☐ OVERHANGING VEGETATION(1) ☐ ROOTWADS(1) ☐ AQUATIC MACROPHYTES(1)
- ☐ SHALLOWS (IN SLOW WATER)(1) ☐ BOULDERS(1) ☐ LOGS OR WOODY DEBRIS(1)

AMOUNT (Check only one or Check 2 and AVERAGE)
- ☐ EXTENSIVE >75%(11)
- ☐ MODERATE 25-75%(7)
- ☐ SPARSE 5-25%(3)
- ☐ NEARLY ABSENT <5%(1)

COMMENTS: ______________

3) CHANNEL MORPHOLOGY: (Check ONLY ONE per Category or Check 2 and AVERAGE) **CHANNEL SCORE** ☐

SINUOSITY	DEVELOPMENT	CHANNELIZATION	STABILITY	MODIFICATION/OTHER	
☐ HIGH(4)	☐ EXCELLENT(7)	☐ NONE(6)	☐ HIGH(3)	☐ SNAGGING	☐ IMPOUND
☐ MODERATE(3)	☐ GOOD(5)	☐ RECOVERED(4)	☐ MODERATE(2)	☐ RELOCATION	☐ ISLAND
☐ LOW(2)	☐ FAIR(3)	☐ RECOVERING(3)	☐ LOW(1)	☐ CANOPY REMOVAL	☐ LEVEED
☐ NONE(1)	☐ POOR(1)	☐ RECENT OR NO RECOVERY(1)		☐ DREDGING	☐ BANK SHAPING
				☐ ONE SIDE CHANNEL MODIFICATION	

COMMENTS: ______________

4) RIPARIAN ZONE AND BANK EROSION: (Check ONE box or Check 2 and AVERAGE per bank) **RIPARIAN SCORE** ☐

River Right Looking Downstream

RIPARIAN WIDTH (per bank)

L R (per bank)
- ☐ ☐ WIDE >150 ft.(4)
- ☐ ☐ MODERATE 30-150 ft.(3)
- ☐ ☐ NARROW 15-30 ft.(2)
- ☐ ☐ VERY NARROW 3-15 ft.(1)
- ☐ ☐ NONE(0)

EROSION/RUNOFF-FLOODPLAIN QUALITY

L R (most predominant per bank)
- ☐ ☐ FOREST, SWAMP(3)
- ☐ ☐ OPEN PASTURE/ROW CROP(0)
- ☐ ☐ RESID.,PARK,NEW FIELD(1)
- ☐ ☐ FENCED PASTURE(1)

L R (per bank)
- ☐ ☐ URBAN OR INDUSTRIAL(0)
- ☐ ☐ SHRUB OR OLD FIELD(2)
- ☐ ☐ CONSERV. TILLAGE(1)
- ☐ ☐ MINING/CONSTRUCTION(0)

BANK EROSION

L R (per bank)
- ☐ ☐ NONE OR LITTLE(3)
- ☐ ☐ MODERATE(2)
- ☐ ☐ HEAVY OR SEVERE(1)

COMMENTS: ______________

5) POOL/GLIDE AND RIFFLE/RUN QUALITY **NO POOL = 0** **POOL SCORE** ☐

MAX.DEPTH (Check 1)
- ☐ >4 ft.(6)
- ☐ 2.4-4 ft.(4)
- ☐ 1.2-2.4 ft.(2)
- ☐ <1.2 ft.(1)
- ☐ <0.6 ft.(Pool=0)(0)

MORPHOLOGY (Check 1)
- ☐ POOL WIDTH>RIFFLE WIDTH(2)
- ☐ POOL WIDTH=RIFFLE WIDTH(1)
- ☐ POOL WIDTH<RIFFLE WIDTH(0)

POOL/RUN/RIFFLE CURRENT VELOCITY (Check all that Apply)
- ☐ TORRENTIAL(-1) ☐ EDDIES(1)
- ☐ FAST(1) ☐ INTERSTITIAL(-1)
- ☐ MODERATE(1) ☐ INTERMITTENT(-2)
- ☐ SLOW(1)

COMMENTS: ______________

RIFFLE SCORE ☐

RIFFLE/RUN DEPTH
- ☐ GENERALLY >4 in. MAX.>20 in.(4)
- ☐ GENERALLY >4 in. MAX.<20 in.(3)
- ☐ GENERALLY 2-4 in.(1)
- ☐ GENERALLY <2 in.(Riffle=0)(0)

RIFFLE/RUN SUBSTRATE
- ☐ STABLE (e.g., Cobble,Boulder)(2)
- ☐ MOD.STABLE (e.g., Pea Gravel)(1)
- ☐ UNSTABLE (Gravel, Sand)(0)
- ☐ NO RIFFLE(0)

RIFFLE/RUN EMBEDDEDNESS
- ☐ EXTENSIVE(-1) ☐ NONE(2)
- ☐ MODERATE(0) ☐ NO RIFFLE(0)
- ☐ LOW(1)

COMMENTS: ______________

6) GRADIENT (FEET/MILE): _____ **% POOL** _____ **% RIFFLE** _____ **% RUN** _____ **GRADIENT SCORE** ☐

APPENDIX 8:

Detailed mIBI Results

APPENDIX 8. Detailed mIBI Results

Site 1. Whetten Ditch:

TABLE A-8.1 Site 1 multi-habitat macroinvertebrate results, July 11-12, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	22		4	88	21.78
Coleoptera	Dytiscidae	2			0	1.98
Coleoptera	Haliplidae	2		7	14	1.98
Diptera	Chironomidae	24		8	192	23.76
Ephemeroptera	Baetidae	2	2	4	8	1.98
Gastropoda	Physidae	22		8	176	21.78
Gastropoda	Planorbidae	1		7	7	0.99
Gastropoda	Unkown	1			0	0.99
Hemiptera	Belostomatidae	1			0	0.99
Hemiptera	Corixidae	18		10	180	17.82
Hemiptera	Gerridae	2		5	10	1.98
Isopoda	Asellidae	3		8	24	2.97
Odonata	Gomphidae	1		1	1	0.99
		101	**2**		**7.216 HBI**	

TABLE A-8.2 Site 1 mIBI metrics, July 11-12, 2001.

		Metric Score
HBI	7.22	0
No. Taxa (family)	13	4
% Dominant Taxa	23.8	6
EPT Index	1	0
EPT Count	2	0
EPT Count/Total Count	0.02	0
EPT Abun./Chir. Abun.	0.08	0
Chironomid Count	24.00	4
mIBI Score		**1.8**

Site 2. Solomon Creek West

TABLE A-8.3 Site 2 multi-habitat macroinvertebrate results, July 11-12, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	1		4	4	0.93
Coleoptera	Dytiscidae	29			0	27.10
Ephemeroptera	Baetidae	1	1	4	4	0.93
Ephemeroptera	Heptageniidae	2	2	4	8	1.87
Ephemeroptera	Tricorythidae	11	11	4	44	10.28
Hemiptera	Corixidae	4		10	40	3.74
Hemiptera	Gerridae	2		5	10	1.87
Isopoda	Asellidae	1		8	8	0.93
Odonata	Gomphidae	1		1	1	0.93
Trichoptera	Brachycentridae	46	46	1	46	42.99
Trichoptera	Hydropsychidae	8	8	4	32	7.48
Trichoptera	Lepidostomatidae	1	1	1	1	0.93
		107	**69**		**2.75 HBI**	

TABLE A-8.4 Site 2 mIBI metrics, July 11-12, 2001.

		Metric Score
HBI	2.75	8
No. Taxa (family)	12	4
% Dominant Taxa	43.0	4
EPT Index	6	6
EPT Count	69	4
EPT Count/Total Count	0.64	6
EPT Abun./Chir. Abun.	N/A	8
Chironomid Count	0.00	8
mIBI Score		**6.0**

Site 3. Hire Ditch

TABLE A-8.5 Site 3 multi-habitat macroinvertebrate results, July 11-12, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Crangonyctidae	29			0	27.10
Coleoptera	Curculionidae	1			0	0.93
Coleoptera	Dytiscidae	8			0	7.48
Coleoptera	Hydrophilidae	1		5	5	0.93
Diptera	Chironomidae	9		8	72	8.41
Diptera	Culcidae	2			0	1.87
Diptera	Stratiomyidae	1			0	0.93
Ephemeroptera	Baetidae	6	6	4	24	5.61
Ephemeroptera	Tricorythidae	1	1	4	4	0.93
Gastropoda	Physidae	3		8	24	2.80
Hemiptera	Gerridae	1		5	5	0.93
Hemiptera	Notonectidae	9			0	8.41
Hemiptera	Veliidae	8			0	7.48
Hirudinea	Piscicolidae	1			0	0.93
Isopoda	Asellidae	28		8	224	26.17
		108	**7**		**7.306 HBI**	

TABLE A-8.6 Site 3 mIBI metrics, July 11-12, 2001.

		Metric Score
HBI	7.31	0
No. Taxa (family)	15	6
% Dominant Taxa	27.1	6
EPT Index	2	0
EPT Count	7	0
EPT Count/Total Count	0.06	0
EPT Abun./Chir. Abun.	0.78	0
Chironomid Count	9.00	6
mIBI Score		**2.3**

Site 4. Juday Ditch

TABLE A-8.7 Site 4 multi-habitat macroinvertebrate results, July 11-12, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Coleoptera	Dytiscidae	1			0	0.93
Coleoptera	Elmidae	1		4	4	0.93
Diptera	Chironomidae	2		8	16	1.87
Gastropoda	Physidae	2		8	16	1.87
Gastropoda	Planorbidae	2		7	14	1.87
Gastropoda	Unkown	93			0	86.92
Hemiptera	Gerridae	1		5	5	0.93
		102	**0**		**6.875 HBI**	

TABLE A-8.8 Site 4 mIBI metrics, July 11-12, 2001.

		Metric Score
HBI	6.88	0
No. Taxa (family)	7	0
% Dominant Taxa	86.9	0
EPT Index	0	0
EPT Count	0	0
EPT Count/Total Count	0.00	0
EPT Abun./Chir. Abun.	0.00	0
Chironomid Count	2.00	8
mIBI Score		**1.0**

Site 5. Blue Ditch

TABLE A-8.9 Site 5 multi-habitat macroinvertebrate results, July 11-12, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Crangonyctidae	12			0	11.21
Amphipoda	Gammaridae	4		4	16	3.74
Amphipoda	Talitridae	1		8	8	0.93
Coleoptera	Haliplidae	2		7	14	1.87
Diptera	Chironomidae	17		8	136	15.89
Diptera	Pelecorhynchidae	1			0	0.93
Ephemeroptera	Baetidae	27	27	4	108	25.23
Ephemeroptera	Baetiscidae	2	2	3	6	1.87
Ephemeroptera	Tricorythidae	1	1	4	4	0.93
Gastropoda	Lymnaeidae	1		6	6	0.93
Hemiptera	Corixidae	30		10	300	28.04
Trichoptera	Hydropsychidae	5	5	4	20	4.67
		103	**35**		**6.867 HBI**	

TABLE A-8.10 Site 5 mIBI metrics, July 11-12, 2001.

		Metric Score
HBI	6.87	0
No. Taxa (family)	12	4
% Dominant Taxa	28.0	6
EPT Index	4	4
EPT Count	35	2
EPT Count/Total Count	0.34	4
EPT Abun./Chir. Abun.	2.06	2
Chironomid Count	17.00	6
mIBI Score		**3.5**

Site 6. Solomon Creek at Meyer Cromwell

TABLE A-8.11 Site 6 multi-habitat macroinvertebrate results, July 11-12, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	7		4	28	6.54
Coleoptera	Dytiscidae	1			0	0.93
Coleoptera	Gyrinidae	1		5	5	0.93
Coleoptera	Haliplidae	1		7	7	0.93
Diptera	Chironomidae	8		8	64	7.48
Diptera	Simuliidae	4		6	24	3.74
Ephemeroptera	Baetidae	65	65	4	260	60.75
Ephemeroptera	Baetiscidae	2	2	3	6	1.87
Gastropoda	Physidae	2		8	16	1.87
Trichoptera	Brachycentridae	1	1	1	1	0.93
Trichoptera	Hydropsychidae	12	12	4	48	11.21
		104	**80**		**4.456 HBI**	

TABLE A-8.12 Site 6 mIBI metrics, July 11-12, 2001.

		Metric Score
HBI	4.46	6
No. Taxa (family)	18	8
% Dominant Taxa	60.7	2
EPT Index	4	4
EPT Count	80	4
EPT Count/Total Count	0.77	8
EPT Abun./Chir. Abun.	10.00	6
Chironomid Count	8.00	6
mIBI Score		**5.5**

Site 7. Solomon Creek East

TABLE A-8.13 Site 7 multi-habitat macroinvertebrate results, July 11-12, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	29		4	116	27.10
Amphipoda	Talitridae	1		8	8	0.93
Bivalvia	Sphaeriidae	2		8	16	1.87
Coleoptera	Elmidae	1		4	4	0.93
Diptera	Chironomidae	12		8	96	11.21
Diptera	Simuliidae	10		6	60	9.35
Ephemeroptera	Baetidae	6	6	4	24	5.61
Ephemeroptera	Heptageniidae	4	4	4	16	3.74
Gastropoda	Ancylidae	3			0	2.80
Gastropoda	Physidae	1		8	8	0.93
Odonata	Calopterygidae	2		5	10	1.87
Odonata	Gomphidae	1		1	1	0.93
Odonata	Lestidae	1		9	9	0.93
Trichoptera	Hydropsychidae	32	32	4	128	29.91
Trichoptera	Phyrganeidae	2	2	4	8	1.87
		107	**44**		**4.846 HBI**	

TABLE A-8.14 Site 7 mIBI metrics, July 11-12, 2001.

		Metric Score
HBI	4.85	4
No. Taxa (family)	15	6
% Dominant Taxa	29.9	6
EPT Index	4	4
EPT Count	44	4
EPT Count/Total Count	0.41	4
EPT Abun./Chir. Abun.	3.67	4
Chironomid Count	12.00	6
mIBI Score		**4.8**

Site 8. Solomon Creek Headwaters

TABLE A-8.15 Site 8 multi-habitat macroinvertebrate results, July 11-12, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	36		4	144	33.64
Coleoptera	Elmidae	2		4	8	1.87
Diptera	Chaoboridae	1			0	0.93
Diptera	Chironomidae	8		8	64	7.48
Diptera	Tabanidae	1		6	6	0.93
Ephemeroptera	Baetidae	3	3	4	12	2.80
Ephemeroptera	Ephemerellidae	2	2	1	2	1.87
Gastropoda	Lymnaeidae	3		6	18	2.80
Gastropoda	Physidae	1		8	8	0.93
Gastropoda	Planorbidae	1		7	7	0.93
Hemiptera	Corixidae	23		10	230	21.50
Hemiptera	Gerridae	8		5	40	7.48
Hemiptera	Veliidae	6			0	5.61
Megaloptera	Sialidae	1		4	4	0.93
Odonata	Aeshnidae	5		3	15	4.67
Odonata	Calopterygidae	1		5	5	0.93
Odonata	Coenagrionidae	1		9	9	0.93
Trichoptera	Hydropsychidae	3	3	4	12	2.80
Trichoptera	Phyrganeidae	1	1	4	4	0.93
		107	**9**		**5.88 HBI**	

TABLE A-8.16 Site 8 mIBI metrics, July 11-12, 2001.

		Metric Score
HBI	5.88	0
No. Taxa (family)	19	8
% Dominant Taxa	33.6	4
EPT Index	4	4
EPT Count	9	0
EPT Count/Total Count	0.08	0
EPT Abun./Chir. Abun.	1.13	2
Chironomid Count	8.00	8
mIBI Score		**3.3**

Site 9. Dry Run

TABLE A-8.17 Site 9 multi-habitat macroinvertebrate results, July 11-12, 2001.

Order	Family	#	EPT	Tolerance (t)	# x t	%
Amphipoda	Gammaridae	5		4	20	4.67
Bivalvia	Sphaeriidae	2		8	16	1.87
Coleoptera	Haliplidae	3		7	21	2.80
Diptera	Chironomidae	65		8	520	60.75
Diptera	Simuliidae	1		6	6	0.93
Ephemeroptera	Baetidae	8	8	4	32	7.48
Gastropoda	Physidae	7		8	56	6.54
Hemiptera	Corixidae	11		10	110	10.28
Platyhelminthes	Planaridae	3		1		2.80
Trichoptera	Hydropsychidae	2	2	4	8	1.87
		107	**10**		**7.374 HBI**	

TABLE A-8.18 Site 9 mIBI metrics, July 11-12, 2001.

		Metric Score
HBI	7.37	0
No. Taxa (family)	10	2
% Dominant Taxa	60.7	2
EPT Index	2	0
EPT Count	10	0
EPT Count/Total Count	0.09	0
EPT Abun./Chir. Abun.	0.15	0
Chironomid Count	65.00	2
mIBI Score		**0.8**